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MEMOIRS OF THE GEOLOGICAL SURVEY.

ENGLAND AND WALES.

THE GEOLOGY

OF THE

NORTHERN PART OF THE ENGLISH LAKE DISTRICT.

QUARTER SHEET 101 S.E.

(INCLUDING SHEETS 63, 64, 69, 70, 71, 76, AND PORTIONS OF 54, 55, 56, 57, 62, 65, 68, 73, 74, 75, CUMBERLAND, AND 12, 18, 19, WESTMORELAND, ON THE SCALE OF SIX INCHES TO A MILE)

BY

J. CLIFTON WARD, Assoc. R.S.M., F.G.S.,

WITH AN APPENDIX ON NEW SPECIES OF FOSSILS, BY R. ETHERIDGE, F.R.S.

PUBLISHED BY ORDER OF THE LORDS COMMISSIONERS OF HER MAJESTY'S TREASURY.

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Fig 1. × 30

Fig 2. × 11

Fig 3. × 16

Fig 4 × 10

Fig 5. × 12

Fig 6 × 15

Fig 7 × 40

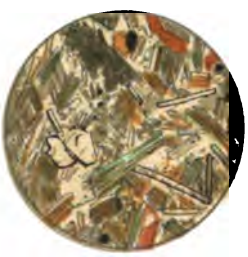

Fig 8 × 58

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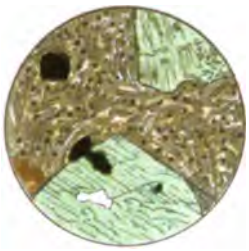

Fig. 9. × 30

Fig. 10 × 18

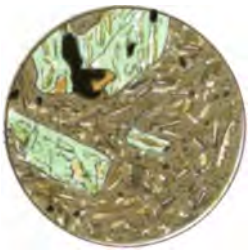

Fig. 11 × 40

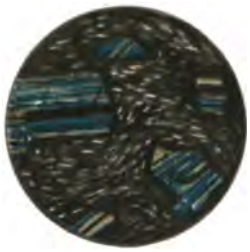

Fig. 12. × 12

Fig. 13 × 18

Fig. 14 × 40

Fig. 15 × 48

Fig. 16 × 30

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Fig. 17 × 45

Fig. 18 × 40

Fig. 19 × 12

Fig. 20 × 40

Fig. 21 × 8

Fig. 22 × 50

Fig. 23 × 60

Fig. 24 × 50

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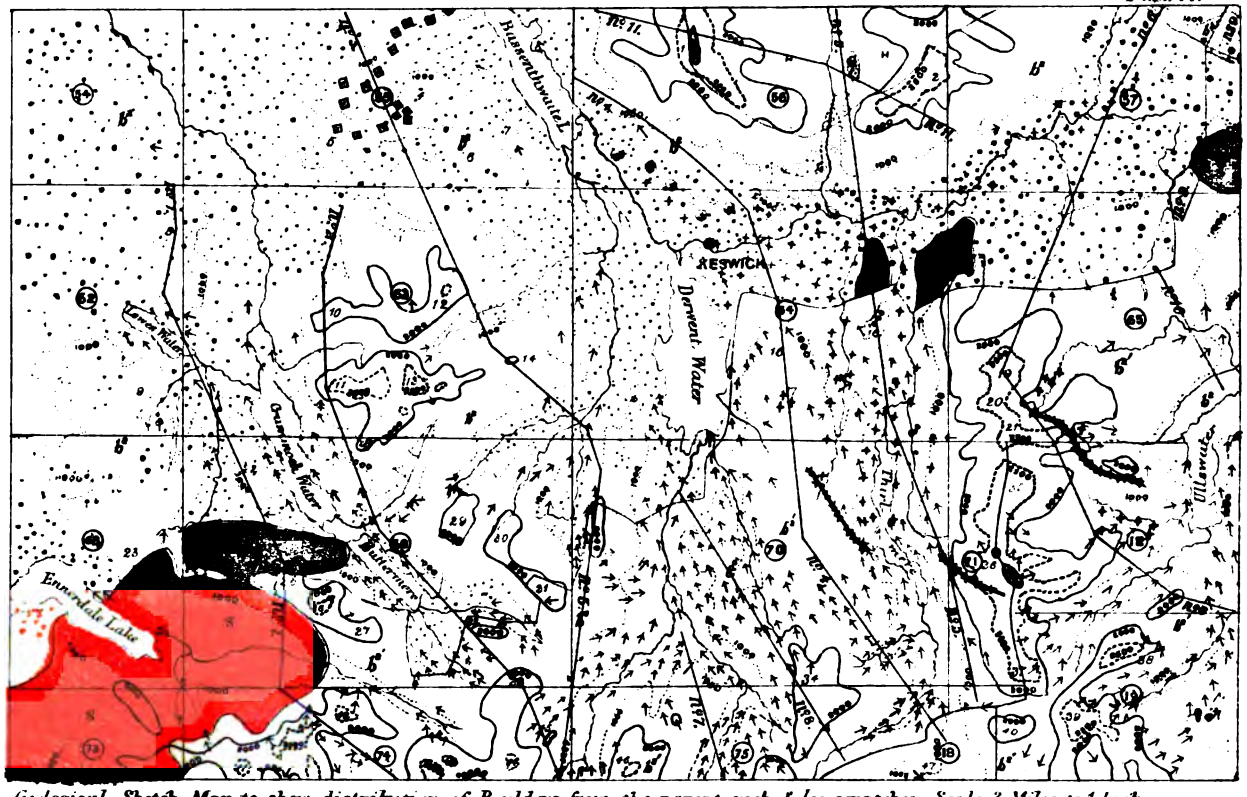
GEOLOGICAL SURVEY OF ENGLAND & WALES.

Plate IV.



Geological Sketch Map to show distribution of Boulders from the parent rock & Ice-scratches. Scale 3 Miles to 1 Inch.
The Arrows represent the position and direction of the ice-scratches. The lines numbered, show the course of the Sections on Plate XI.

1000 Contour ___ 2000 Contour .... 2500 Contour ___ 3000 Contour [6] Denote corresponding Six-inch Maps.

Pavement Conglomerate (Old Red.)
b¹ Skiddaw Slate
Mineth (Slate Fell) & boulders
Syenite & Q Felsh boulders
b² Volcanic Series & boulders
Armboth & Helvellyn Dyke and boulders
Granite
H Spotted Schist. boulders

Small figures refer to the Names and Heights of the Mountains as given on opposite Page.

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NOTICE.

THE tract of country comprised in Quarter-Sheet 101 S.E. was surveyed, under the superintendence of Mr. W. T. Aveline, District Surveyor, by Mr. J. C. Ward, by whom this Memoir has also been written.

Being the first Memoir on the geology of this particular district issued by the Geological Survey, it has been allowed to exceed the usual limits to which the explanations of such small areas as those comprised in quarter-sheets have hitherto extended, as it affords a general description of the rocks and of the complicated geological structure of a special area which will apply more or less to the whole of the English Lake District.

The lists of fossils and the whole of the palæontological information have been revised by Mr. Etheridge with his usual care. He has also contributed, in an appendix, a description of some new fossils occurring in the Arenig or Skiddaw Slates, which were found by Mr. Kenzie Dover, and lent to Mr. Etheridge during the progress of the survey for illustration and identification.

Mr. Ward has been assisted by Mr. W. Whitaker in completing the list of works and papers bearing on the geology of the country which is described in the Memoir.

H. W. BRISTOW,
Senior Director.

Geological Survey Office,
28, Jermyn Street, London, S.W.
1st June 1876.

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References to Plate IV.

Numbers on Sketch Map.	Names of Mountains.	Height above Sea-level.	Numbers on Sketch Map.	Names of Mountains.	Height above Sea-level.
1	Skiddaw - -	3,054	26	High Stile - -	2,643
2	Blencathra - -	2,847	27	High Crag - -	2,443
3	Mell Fell - -	1,760	28	Whiteless Pike -	2,159
4	Broom Fell - -	1,670	29	Robinson - -	2,417
5	Kirk Fell - -	1,476	30	Hindscarth - -	2,385
6	Lord's Seat - -	1,811	31	Dale Head - -	2,473
7	Barf - - -	1,536	32	Fleetwith Pike (Honister Crag).	2,126
8	Fellbarrow - -	1,363			
9	Carling Knott -	1,781	33	Grey Knotts - -	2,287
10	Whiteside - -	2,317	34	Ullscarf - -	2,370
11	Grasmoor - -	2,791	35	Raise - - -	2,889
12	Grisedale Pike -	2,593	36	Helvellyn - -	3,118
13	Crag Hill - -	2,749	37	Dollywaggon Pike -	2,818
14	Causey Pike - -	2,082	38	Gavel Pike - -	2,577
15	Cat Bells - -	1,482	39	Fairfield - -	2,862
16	Wallow Crag - -	1,233	40	Seat Sandal - -	2,415
17	Bleaberry Fell -	1,932	41	Haycock -	2,619
18	High Rigg - -	1,162	42	Pillar - - -	2,926
19	Great Dodd - -	2,807	43	Kirk Fell - -	2,630
20	Watson's Dodd -	2,584	44	Green Gable (Great Gable a little to the S. beyond edge of map).	2,948
21	Stybarrow Dodd -	2,756			
22	Mellbreak - -	1,676			
23	Great Borne - -	2,019	45	Base Brown - -	2,120
24	Starling Dodd - -	2,084	46	Glaramara -	2,560
25	Red Pike - -	2,479	47	Steel Fell - -	1,811

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THE GEOLOGY OF THE NORTHERN PART OF THE ENGLISH LAKE DISTRICT.

CHAPTER I.

PHYSICAL GEOGRAPHY OF THE DISTRICT.

That portion of the English Lake District briefly to be described in the following pages, lies almost wholly upon the north side of the main watershed of the country, running approximately east and west. This line of watershed passes through the following points. Beginning a little south of Ennerdale Lake its course is by Caw Fell (2,188 ft.), Haycock, 41* (2,619), Pillar, 42 (2,927), Kirk Fell, 43 (2,631), Great Gable (2,940), Sty Head (1,620), Great End (2,982), Esk Hause (2,490), north end of Bow Fell (2,800), Black Crags (1,922), Stake Pass (1,575), Thunacar Knott (2,351), Sergeant Man (2,374), Steel Fell (1,811), Dunmail Raise (783), Seat Sandal, 40 (2,415), Grisedale Pass (1,930), Fairfield, 39 (2,863), Little Hart Crag (2,090), Red Screes (2,509), and Kirkstone Pass (1,481). Further east, beyond the boundaries of the area under description, it passes over High Street, Harter Fell, and Harrop Pike, to Wasdale Pike.

On the north the area is bounded by a line running due east from Cockermouth, through the northern part of Skiddaw (1)*, to Eycott Hill. On the west, by a north and south line from Cockermouth to the south of Ennerdale. And on the east by a north and south line from Eycott Hill and Mell Fell (3) to Kirkstone Pass.

Approaching the district from the east, and passing westwards across it, the mountains present themselves in the following groups and ranges. Looking northwards from Threlkeld is the deeply ravined front of Blencathra (2), perhaps the noblest of our mountains. Due south, the Vale of St. John, deep, narrow, and craggy on either side, separates the northern end of the Helvellyn range from the low but rugged Naddle Fell, while the upland continuation of this valley, containing the long river-like Thirlmere, parts all the loftier part of the grassy Helvellyn line of mountains from the wild and ofttimes craggy table land extending from Ullscarf (34), on the south, to Castlerigg Fell (17), on the north.

Moving westwards, to Keswick, the mountains appear perhaps to their greatest perfection. Standing at one end of a rich, fertile, and well-wooded tract of alluvium uniting the two lakes of

* Mountains numbered on Plate IV.

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Derwentwater and Bassenthwaite, the double-peaked, lofty, but smooth-sided Skiddaw rears his noble front upon the north. Southwards, Derwentwater, with its well-wooded islands, lies nestled among hills of beautiful and varied aspect; upon the one side all craggy, precipitous, and of irregular outline; upon the other, of smoothly sloping aspect and gently curved contour. At the head of the lake opens up Borrowdale, with the round-topped Castle Crag, standing like sentinel at its entrance, and bold, rough, craggy mountains, surrounding on all sides the grass-clad valley bottom. As seen from Keswick, the hummocky outline of Glaramara (46), the straight-edged, lofty cliff of Great End, and the slightly conical form of Scafell Pikes, combine to form such a noble background to this view, as to render it, I believe, quite unrivalled in British scenery.

West of Derwentwater and Bassenthwaite, the smooth and softly-outlined mountains form wonderfully perfect groups, between which sweep down green and richly cultivated valleys affording glimpses through their openings of mountains far beyond. Crossing this range, a third large north and south valley is reached, in its upper part the resting place of Buttermere and Crummock Water, and in its lower, forming the quiet and pastoral Vale of Lorton. Upon its east side, and at its upper end, the mountains are lofty and precipitous, giving rise to some very striking and impressive scenery, especially as viewed from the foot of Crummock Water, or on descending the hill-side above Buttermere village. Upon the west side, *below* Crummock, the mountains are less lofty, though often steep-sided, and the pretty little Loweswater drains down into Crummock from amongst them.

If the traveller climb over the southern walls of the rock-girt head of the Buttermere vale, he will find at his feet, to the south, yet another wide and deep valley, its course nearly east and west, its sides rocky and precipitous in the extreme, at its head the giant-like Great Gable, and at its foot the loch-like Ennerdale Lake. One more climb, over a still loftier ridge than the last, will afford a glimpse into the wild upper branches of Wastdale, very little of which, however, comes into our present district.

Besides these main valleys and their parting mountain ridges, the western half of the Ullswater valley, or Patterdale, is included in the area under description. The Hellvellyn range is far finer on the eastern side than on the western, being hollowed out beneath its summit into picturesque combs, containing small tarns, and separated from one another by narrow and lofty edges. Several fine dales, also, branch off eastwards from this mountain ridge to join the main valley of Ullswater, which runs northwards in the upper part of its course.

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CHAPTER II.

GENERAL DESCRIPTION OF THE ROCKS.

The following rock groups are found within the area under description*:—

Alluvium.
Glacial deposits.
Palæozoic.
4. *Carboniferous Limestone.*
3. *Basement Conglomerate* (often called Upper Old Red).
Lower Silurian.
2. *Volcanic Series of Borrowdale* (Green Slates and Porphyries).
1. *Skiddaw Slates.*
Igneous and Metamorphic Rocks.

Each of the four Palæozoic groups will now be described in general terms.

1. Skiddaw Slates.

Consist of many alternations of mud, sand, and grit deposits, now converted into slate, sandstone, and gritstone, and these metamorphosed in some parts into Chiastolite Slate, Spotted Schist, and Mica Schist. No beds of limestone occur in the series, and the traces of the ancient life of the period are scant.

2. Volcanic Series of Borrowdale.

The rocks of this series seem almost wholly to be made up of volcanic material. This consists of beds of volcanic ash and breccia, alternating with ancient sheets of lava, and the whole traversed by dykes and masses of intrusive igneous rock. Fossils are altogether absent.

3. Basement Conglomerate.

Beds of red conglomerate and breccia, with occasional fine sandy parts.

4. Carboniferous Limestone.

Like the previous formation, occurs to a very limited extent in this area. Consists of frequent alternations of grey limestone and friable, red, and gritty sandstone, with an occasional thin coal-seam.

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* For the *probable* correlation of the Lower Silurians of this district with those of Wales, see pages 46 and 47.

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*Meaning of Names employed for Igneous and Metamorphic Rocks.**

1. *Granite.* Quartz, felspar, and mica.
2. *Hornblendic* (*Syenitic*) *Granite.*—Quartz, felspar, and mica, with more or less hornblende.
3. *Syenite.*—Felspar and hornblende, with but little or no quartz.
4. *Minette* (*Mica Trap*).—Felspar and mica, with but little or no quartz.
5. *Quartz Felsite.*—(Quartz Porphyry, Elvanite.) Crystals of quartz and felspar in a felsitic base.

(In Nos. 1 to 5 both orthoclase and oligoclase are present, but the former usually predominates.)

6. *Felstone.*—Compact flint-like rock, with the average chemical composition of granite, but in which the process of crystallization is incomplete.

7. *Diorite* (*Greenstone*).—Crystalline mixture of hornblende and plagioclase felspar.
8. *Quartz Diorite*—Hornblende, plagioclase, and quartz.

9. *Dolerite.*—Crystalline mixture of plagioclase (labradorite), augite, and magnetite. Crystalline structure evident to the naked eye.
10. *Basalt.*—A compact dolerite. Crystalline structure *not* evident to the naked eye.
11. *Diabase.*—Probably an altered doleritic rock, containing chlorite.

(Nos. 9 to 11 are both intrusive and contemporaneous.)

12. *Felsi-dolerite.*—Contemporaneous trap (lava) intermediate between felstones and dolerites.

13. *Volcanic Breccia.*—Rock made up of angular fragments from the size of a shilling upwards.
14. *Volcanic Ash.*—Rock made up of fragments from the size of a shilling to the finest powder.
15. *Ash Conglomerate.*—Rock made up of fragments rounded *after* ejection.

16. *Trap.*—General term for intrusive or contemporaneous igneous rocks of a doubtful nature.

17. *Chiastolite Slate.*—Cleaved argillaceous, sedimentary rock, with scattered chiastolite crystals.
18. *Spotted* (*or Andalusite*) *Schist* (*Knotenschiefer*). An imperfectly foliated rock, with numerous spots (undeveloped chiastolite) and chiastolite crystals; passing into mica schist.
19. *Mica Schist.*—Foliated rock, consisting *mainly* of mica and quartz.

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* It is impossible in all cases to distinguish between these two classes. An igneous rock has been formed under considerable heat and pressure, is generally more or less intrusive or eruptive, and may be an extreme of metamorphism.

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CHAPTER III.

DESCRIPTION OF THE ROCKS—*continued.**

1. Skiddaw Slate, including its Metamorphic Portions.

General Character.—Typical Skiddaw Slate is a black or dark-grey rock, often much cleaved, but splitting for the most part into small flaky pieces or splintery pencil-like fragments, and seldom forming anything like good workable slate. Occasionally this rock is a soft, black shale, exactly like that of Carboniferous age, and in other parts it is earthy and concretionary, with included irony nodules, which sometimes show a cone-in-cone structure.

Interstratified with slate of the above character, and occasionally forming beds of a considerable but inconstant and irregular thickness, occurs a more or less hard, sandy, and often micaceous slate, sometimes quite flaggy and current-marked, now and then massive and much jointed, so as to appear quite columnar, and more rarely, having a somewhat coarse, gritty character. When the cleavage is undeveloped or coincides with the bedding of the sandy slate, there occasionally occur good flags of varying thickness, which are sometimes used for paving and building purposes, and frequently for walling. There is, however, little material in this series of rocks of much economic value, with the exception of mineral veins traversing them, to be described hereafter.

Such are the general characters of the Skiddaw Slate where not much metamorphosed. In several parts of the district, however, metamorphism has caused great changes in it.

Altered Skiddaw Slates.—Besides the normal amount of alteration common to all sedimentary rocks through ordinary pressure and shrinkage—the latter producing joints—we may distinguish the following phases:—

a. Intense *lateral* pressure.—This has evidently acted with great force upon the various beds, crumpling, contorting, and cleaving them. From the nature of the case, the finer the particles the more readily could they adapt themselves to altered circumstances, hence while the fine-grained hardened mud is much cleaved, the sandy beds are less so, and the hard, coarse-grained, and gritty strata are seldom or little affected.

As it would seem that the same lateral pressure which caused the cleavage, produced also the contortion of the strata, or vice-versâ, and since the former is tolerably uniform over considerable areas both in direction and amount, and the latter very varied, it must of necessity follow that the planes of cleavage cut those of bedding at all sorts of angles, the two only occasionally coinciding.

b. Action from below.—There are cases in which the slate is altered and hardened over considerable areas, *distant* from any intrusive mass of igneous rock.† Since the alteration is similar to that prevailing in the same beds immediately around igneous

* Specimens of all the rocks of this northern half of the Lake District are preserved in the Keswick Museum, with references to the various 6-inch maps.

† See note on p. 4.

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centres, it is right to infer that with all probability the change is due to the action of intrusive rocks *beneath*, which have not been exposed at the surface by denudation.

c. Alteration around Quartz Veins.—Many parts of the slate are traversed by numerous quartz veins, some of considerable thickness, others in the form of threads and strings. The slate immediately around them often appears much hardened and altered. They seem frequently to have been produced whilst the contortion was going on deep beneath the surface, and to have been deposited from solution rapidly, since the generally opaque whiteness of the quartz is due to the immense number of minute liquid-cavities it contains. According to Sorby,* the quartz of such veins "was deposited from water holding various salts and acids in solution, at a temperature varying from about 200° C. to a dull red heat visible in the dark." If this be so, there need be no wonder that a certain amount of alteration has been effected in the rocks around them.

d. Alteration around masses of Igneous Rock.—The amount of metamorphism around such rocks as intrusive diorite, dolerite, quartz felsite, and granite, is very varied in amount and oftentimes seemingly capricious in character.

(d.) 1. *Alteration around Dioritic and Doleritic dykes and bosses.*

The slate, around the many small intrusive dykes and bosses of Diorite and Dolerite, is often but little altered. Very seldom is there any sensible effect to greater distances than a few yards.

(d.) 2. *Alteration around Ennerdale and Buttermere Syenitic Granite.*

Here the change that has taken place in the slate is very marked. There are, it is true, one or two spots where it seems but little altered, but generally, for a considerable distance from the edge of the syenitic granite, it is converted into a very compact, felstone-like, or even flinty-looking rock, with occasionally a very decided banded structure, weathering on the outside like lines of bedding. If a fragment of such a rock be cut at right angles to the lines, the appearance represented in Fig. 1., Plate VI., is seen, in which *a b* is part of the outer surface showing weathered ridges and hollows; and *c d*, the smooth, cut surface, of a light grey-blue colour, traversed by parallel bands of a greenish mineral, frequently inclosing lenticular spaces between them. The part, with toothed inner edge, between *e* and *f*, represents the weathered margin of the specimen, and is of a light brown colour. The rock is very irony along the rather frequent joint lines. A thin slice, cut from the surface just described, and viewed under the microscope by transmitted light, yields the following interesting results.

Under a high power (⅛-inch objective), the green mineral, collected *chiefly* along bands, is seen, in parts, to consist of longish crystals arranged frequently in a fan-like form, in other parts it forms a network, the meshes of which are composed of grains of quartz, with scattered crystals and grains of magnetite. On testing for dichroism, the green mineral is found to be markedly

* "Structure of Crystals," *Quart. Journ. Geol. Soc.*, vol. xiv. p. 474.

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dichroic in parts and faintly so in others, which character, combined with the comb-like arrangement of the crystals, shows it most likely to be chlorite.*

In polarized light, the chlorite shows its usual colours where crystallised, and the hazy base breaks up into a coloured breccia, the colours changing to their complementaries on rotating either of the prisms.

In some cases the quartz seems to be decidedly crystalline, in other cases it is more irregular; it frequently forms bands running parallel with those of the chlorite. In one of the larger quartz spaces, showing a fine blue colour in one position of the prisms, I carefully noted the following facts. There were several small liquid-cavities, the $\frac{1}{10000}$th of an inch in diameter,† each with its minute vacuity moving freely about in the liquid; several glass-cavities of light green colour, with a brownish tinge, and slightly dichroic, containing in some cases two or three round black spots, probably minute bubbles, in which the central spot of light was too small to be discernible; one or two combined glass and stone-cavities; one perfect square of magnetite, the $\frac{1}{5000}$th of an inch‡; several slender needle-like crystals, to the sides of one of which were attached two round bubbles, like gas or vapour-cavities (?); and one shorter and thicker prismatic crystal apparently ending in a stone-cavity. These rod-like crystals are probably schorl. Now, according to Sorby's investigations, such a combination of glass, stone, and fluid-cavities, proves that the rock was metamorphosed "under great pressure by the combined influence of liquid water and melted stone."§ The period when this metamorphism took place will be discussed in another chapter, also the microscopic structure of the neighbouring syenitic granite.

Another specimen of similarly altered slate, from the summit of Red Pike (*see* Section I., Plate XI.), shows the same general microscopic structure, and its chemical composition is given in the following analysis :—‖

Silica	54·480
Alumina	20·720
Lime	1·624
Magnesia	1·946
Potash	3·203
Soda	6·217
Ferrous oxide	8·188
Ferric oxide	·988
Phosphoric acid	·569
Sulphuric acid	trace
Carbonic acid	trace
Carbonaceous matter	·361
Water	1·704
	100·000

* There may be some traces of hornblende as well, but the mass of the green mineral is probably chlorite or one of its allies.

† In this case, a ¼-inch objective was used with a C eye-piece, giving a magnifying power of 665 times. By employing a Jackson's micrometer with this combination, measurements to less than $\frac{1}{10000}$th of an inch are readily made.

‡ Very likely a section of an octahedron.

§ "Structure of Crystals," *Quart. Journ. Geol. Soc.* vol. xiv., p. 468.

‖ This, and all succeeding analyses given in these pages, have been made for me by Mr. John Hughes, F.C.S.

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(d.) 3. *Alteration around St. John's Quartz Felsite.*

The alteration in this case cannot be so well observed as in the last, since there are fewer clear sections surrounding the felsite. In some spots the slate seems quite unaltered close up to the igneous mass, but this may be, and certainly is in some instances, the result of subsequent faulting. Apparent beds of altered slate quite run through the felsite in places, as just north of St. John's Chapel; and in others, as at Clough Head, the slate is converted into a hard, compact rock, often much iron-stained, or into a hornstone. In some such cases it becomes exceedingly difficult to know where to draw the line of division. On surveying the ground in 1872, I collected specimens illustrating the gradual passage from well-marked slate to well-marked felsite, distinguishing four stages, thus :—

Quartz Felsite, 1st stage, 2nd stage, 3rd stage, 4th stage, *Slate*. —Within the last year I have had thin slices cut from specimens belonging to the 3rd and 4th stages, and their microscopic examination yields the following results :—

In the 4th stage, the rock, essentially a slate, is found to consist of minute grains upon a somewhat hazy base. Scattered among the granules and collected along net-like patchy lines, there is a great deal of chloritic matter, in particles, scales, and radiate and fan-like crystalline groups. Under polarized light, with crossed prisms, there is no absolute darkness, but rather a partial felsitic reaction in the base, although the net-work bands, owing to the close aggregation of particles, often appear darker than the rest of the field. Much of the hazy base is evidently formed of imperfectly crystalline quartz. There are also many minute grains of magnetite and carbon (?) scattered about.

In the 3rd stage the rock is a good deal harder than that of the 4th stage, which, though compact-looking, had much of the softness of the unaltered slate. The thin slice, moreover, when viewed with the naked eye, has none of the general granular appearance of the last, but shows distinct indications of both felspar and quartz crystals. Under the microscope, however, there is a good deal of the same granular structure to be seen upon a whitish hazy ground, with here and there chlorite crystallising out in comb-like fronds. But scattered plentifully throughout the base are many sections of partially perfect quartz crystals, containing some small liquid-cavities, glass and stone cavities, occasional grains of magnetite, and clear light-green acicular crystals which frequently project into their centres from the sides. In one of these quartz crystals, a minute hexagonal scale was observed, probably of hæmatite. Every here and there are partially formed crystals of orthoclase, and flakes of a greenish mica. In polarised light the base shows the reaction characteristic of a felsitic structure.

The specimens of the 2nd and 1st stages approach still nearer to the typical quartz felsite, and it should be remarked that both in this case and that of the altered slate around the Ennerdale syenitic granite, there is much more evidence in the internal microscopic structure of extreme alteration than in the weathered exterior, which, in all these three examples described in detail, is

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certainly much more slaty-looking than felsitic. From this, and facts afterwards to be noticed when speaking of altered ash, I should be rather led to infer that among highly metamorphosed rocks the weathered exterior is likely to give more true indication of what the rock *originally* was than even the internal microscopic structure, although the examination of this last is invaluable inasmuch as it *proves* the large amount of alteration which the rock has undergone, a fact that might probably not have been suspected from the exterior alone. The period of this metamorphism, and the structure of the St. John's quartz felsite will, as in the last instance, be treated of in succeeding chapters.

(d.) 4. *Alteration around Skiddaw Granite.*

Only the very small area of granite seen along the course of Sinen Gill comes within the area of the Map 101 S.E., but as it is doubtless connected beneath the surface with the larger mass in the Caldew Valley, a mile to the north, the alteration effected in the slate is most probably due to a large development of granite beneath the tract of Skiddaw Forest, which is, however, only exposed by denudation at certain spots.

Since the metamorphosed area is one of considerable size—five or six miles from east to west and about as many from north to south—it will be seen that in all probability Skiddaw Slate of very varying texture has been affected; in some places the beds may have been argillaceous, in others, sandy; hence we may expect to find the metamorphic rocks produced from them varying likewise. In general, the following is the order in which the metamorphism has taken place:—On approaching the altered area, the slate first becomes faintly spotty, the spots being of a somewhat oblong or oval form, and a few crystals of chiastolite appear. Then these crystals become more numerous, so as to entitle the rock to the name of Chiastolite Slate. This passes into a harder, more thickly bedded, foliated and massive rock, Spotted (or Andalusite) Schist; and this again into Mica Schist of a generally grey or brown colour, and occurring immediately around the granite.

The general microscopic structure of each of these rocks will now be described.

Chiastolite Slate (Fig. 2, Plate I.).—The following description is given as a sample of fully developed chiastolite slate, near its passage into the Schist. In appearance it is a greyish-black, cleaved rock, with spots often weathering white upon the surface, occasionally a good deal of iron-pyrites, and crystals of chiastolite traversing the slate in various directions.

The general microscopic appearance of such a specimen is represented in Fig. 2, Plate I. Viewed with a high power, the base is found to consist of a fine wavy mesh-work of a green mineral much mingled with brown matter. The open meshes are clear and are drawn out in the direction of the cleavage. Many small transparent prisms exhibit bright colours under polarised light, changing from green to red, and probably represent some form of andalusite. There are also dark brown patches of ferric

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oxide, which appear in the slice as brown spots, and much of the same material is drawn out into strings in the direction of the cleavage. Having the same general course, also, are numerous short black rods and bars, probably of pyrites. Crystals of chiastolite, showing colour under polarized light, and containing collections of carbon particles, are frequent. The wavy meshes of the base sometimes appear to bend on approaching the sides of one of these crystals. Under polarised light some of the larger mesh-spaces (though all are very minute) appear to be imperfectly crystallised chiastolite, while others are quartz.

The following is an analysis of Chiastolite Slate from How Gill, Skiddaw, fully two miles from the granite of Sinen Gill; the rock here presents the ordinary characters of Skiddaw Slate, with the exception that numerous crystals of chiastolite traverse it in all directions:—

Silica	65·725
Alumina	14·182
Lime	1·176
Magnesia	2·342
Potash	3·261
Soda	1·981
Ferrous oxide	7·306
Ferric oxide	trace
Bisulphide of iron	trace
Phosphoric acid	trace
Sulphuric acid	·294
Carbonic acid	trace
Carbonaceous matter	2·035
Water	1·698
	100·000

Spotted (*or Andalusite*) *Schist* (Fig. 3, Plate I.).—In thin slices and upon the cut surface of the rock, numerous small spots are seen, of more or less rectangular or oblong form, appearing dark upon the rock face but of a pale colour when viewed by transmitted light. These spots are usually arranged with their longer axes in the direction of the planes of incipient foliation and cleavage, which here agree.

This rock is locally known as Hornblende Slate, but a microscopic examination of specimens from various parts shows that hornblende is a comparatively rare constituent,* whereas andalusite in some form is common. It undoubtedly corresponds to the Knotenschiefer of the Germans. The small and slightly oblong spots which occur throughout are undeveloped crystals of chiastolite, and this mineral may be seen in all stages of its formation. Then, surrounding and enveloping these, are numberless short prisms of andalusite (?) sometimes forming quite a flowing crystalline base, and being much mingled with flakes of mica and more or less quartz. There are also many black bars and patches, partly consisting of pyrites, and partly of carbon particles (?) All the constituents, even to the black bars, for

* Mr. Allport, who has examined several slices of this rock, agrees with me in this conclusion.

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the *most* part lie along the planes of cleavage and partial foliation. With a high power it is almost impossible to find the boundaries of the oblong rectangular spots, since they are in no case definite lines, unless, as in Fig. 3, Plate I., one of the thin brown veins forms an apparent boundary. A little examination, however, with various powers, shows clearly that these spots are only partially developed crystals of chiastolite, and a substitution of mica for andalusite has taken place around and sometimes within the concretionary spots.

Much of the description above given answers to what is seen with a higher power than that used for the drawing in Fig. 3, Plate I.

The following is an analysis of a typical specimen of this rock from Skiddaw Forest; it is of a grey-blue colour, crowded with small dark spots of somewhat hazy outline; minute specks of mica occur throughout, and there is an imperfect foliation:—*

Silica	54·448
Alumina	23·930
Lime	1·288
Magnesia	2·379
Potash	3·010
Soda	2·086
Ferrous oxide	8·883
Ferric oxide	trace
Bisulphide of iron	1·801
Phosphoric acid	·085
Sulphuric acid	trace
Carbonic acid	trace
Carbonaceous matter	·792
Water	1·298
	100·000

Mica Schist (Fig. 1, Plate I.).—This is a grey or brownish, and often rather sandy-looking rock, with distinct foliations of mica, but by no means a typical mica schist.

Under the microscope it is seen to consist of quartz and two micas, brown and white, the quartz sometimes keeping in well-defined lines. Some specimens contain a few of the hazy chiastolitic spots or well developed crystals of andalusite or chiastolite, and occasionally of felspar. Hæmatite frequently occurs, and the carbon particles seem not to be wholly absent. In Fig. 1, Plate I., the striated flakes are the micas; the red patches, hæmatite; and the clear intervening spaces, quartz.

The following analysis is that of a specimen of mica schist from the junction with the granite of Sinen Gill, and should be compared with the analysis of the granite itself given on page 30:—

Silica	53·174
Alumina	24·460
Lime	1·512
Magnesia	1·946

* Such a rock has been used for the formation of sets of musical stones, for which it seems specially adapted; several of these interesting musical instruments may be seen in Keswick.

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Potash - - - - -	5·037
Soda - - - - -	2·930
Ferrous oxide - - - -	8·634
Ferric oxide - - - -	·246
Phosphoric acid - - - -	·128
Sulphuric acid - - - -	trace
Carbonic acid - - - -	trace
Carbonaceous matter - - -	·717
Water - - - - -	1·216
	100·000

Such is the microscopic structure of the metamorphic rocks around these granitic masses. Variations there are many, probably in great part due, as before hinted, to the variation in composition of the original rocks. Thus, much of the mica-schist seems very rich in quartz, and in all probability this was formed out of sandy beds. Other parts are more micaceous, apparently, than quartzose, and these very likely represent original argillaceous strata.

Thus, the order of change which has taken place, seems to be the following:—The clay-slate at first becomes full of small concretionary spots, which increase in distinctness until many assume the form of perfectly developed chiastolite crystals; accompanying these, in the general base, are numerous *very minute* prisms, most likely some form of andalusite. As the metamorphism increases, the concretions are still largely developed (Knotenschiefer), appearing as rectangular spots, but the base gradually becomes quartzose and micaceous; in this state the rock is intermediate between andalusite schist and mica schist. Lastly, the concretions more or less disappear, and the whole mass is made up of a mixture of quartz and two micas.*

The passage is generally very gradual. The foliation, also, is varied in its completeness, and seems in most cases to be developed along the cleavage planes, which have a tolerably regular dip to the south-east of from 50° to 70°. In some places, however, especially near the granite, it is very contorted and folded, having very much the appearance of bedding. Sometimes small quartz veins run along these contorted foliations, formed most likely at the very period of metamorphism (*see* previous remarks on Quartz Veins, page 6). It seems probable, in the present instance, that the partial foliation was produced by metamorphism after the cleavage had been effected by lateral pressure, or that it was an extension of the same process, and hence the former took place mostly along the planes of the latter, though becoming developed along some of the original bedding planes where the character of the rocks had prevented a perfect cleavage.†

* A very similar series of changes has been observed by Fuchs in the metamorphism of the clay-slate of St. Savieur, in the Pyrenees. "Die alter Sediment-" Formationen und ihre metamorphose in den Französichen Pyrenäen," Leonhard. Jahrbuch, 1870, p. 717.

† See also Chap. XI. *Theoretic* subjects connected with the granites of the district are being treated by the author in papers brought before the Geological Society.

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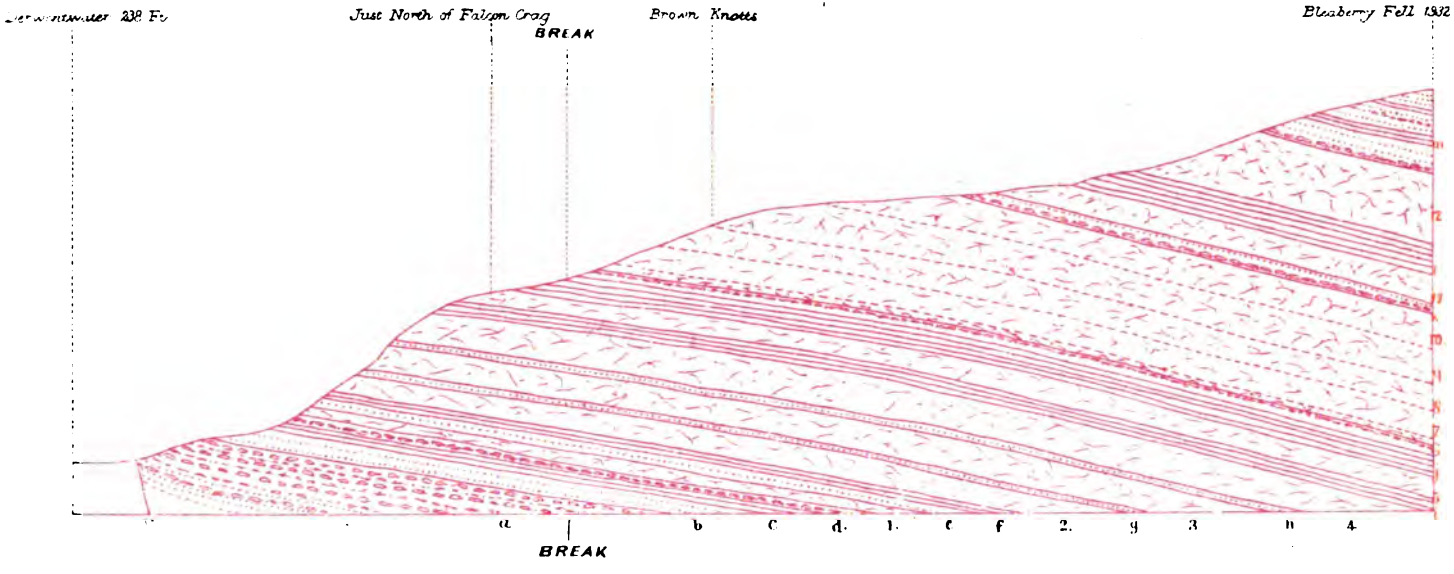

Section from the Lake-edge (S. end of Great Wood), through the Falcon Crag hill-side to Bleaberry Fell. ¼ Miles S of Keswick

Scale, 6 Inches to 1 Mile. S L = Skiddaw Slate. F = Fault. Small letters denote beds of ash and breccia. = Breccia. = Rough and coarse ash. = Fine and bedded ash. Figures denote lava beds. = Lava.

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CHAPTER IV.

DESCRIPTION OF THE ROCKS—*continued.*

2. Volcanic Series of Borrowdale.

In substituting the name of "Volcanic Series of Borrowdale for that of "Green Slates and Porphyries," I follow the proposition of Profs. Harkness and Nicholson, as given in a paper by the latter in 1872.* The old name given by Prof. Sedgwick, while applicable to a part of the group, by no means represents the character of the whole, and since the term "porphyry" as a *generic* name is in all probability doomed, its use in an adjective form being alone retained, it would seem better to call this grou of rocks after the place where most typically developed.

(a.) *Typical section of lavas and ashes.*

This series of anciently erupted lavas and ashes presents many points of great interest. Perhaps the best general introduction to it will be to examine in some detail a typical section of these rocks at some easily accessible spot. There could scarcely be a more instructive, and at the same time charming excursion, than one made upon the somewhat steep mountain side overhanging the eastern shores of Derwentwater. A walk of a mile and a half out of Keswick upon the Borrowdale Road will bring the traveller to the southern end of the so-called "Great Wood." On his right there lie the wood-fringed shores of the lake, and on his left a steep and rocky hill-side, with Falcon Crag standing out nobly like some giant fortress. Skirting the edge of the Great Wood is Cat Gill, which has cut out for itself a deep and rocky ravine, well worth exploring. Between this Gill and Falcon Crag the ascent may be readily made, with a little zig-zagging and many a halt, and the rocks met with in the course of the climb will now be described in detail. If the reader will refer to Plate V., the description will be readily understood. The various beds of lava are spoken of as Nos. 1, 2, &c., while the intermediate deposits of ash are denoted by lettering.

Just below the road, at the wood-end, is the fault which throws the Skiddaw Slates against this Volcanic Series, and upon the opposite side is a picturesque group of rocks of purple breccia, some of the large jointed blocks standing out from the rest like fragments of Cyclopean masonry. This purple breccia (*a*) is one of the lowest beds of the series in this district. On beginning the ascent, a small area is passed over without any clear section being shown, until the foot of the first low crag is reached, due south of the almost right-angled bend of Cat Gill. Here, No. 1 lava is seen lying upon a thin bed of brecciated ash (*d*), with bedded ash (*c*) below it.

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* Appendix, 63. (The number refers to the list of titles.)

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No. 1 is very thin, at this spot not more than 20 feet.* Its base is brecciated (*d*), as very commonly happens with these as with modern lavas; in fact, both the bottom of the lava which flowed over a cool surface and the top which must often have rolled over itself in loose clinkers, like many of the recent Vesuvian flows, show either a vesicular or a decidedly slaggy and brecciated structure. The character of No. 1 is exceedingly compact, breaking much along weathered joints, or with a conchoidal fracture; the colour is bluish-green, with many soft black spots, for the most part probably pseudomorphs after augite.

Next comes a small thickness of purplish ash (*e*), succeeded in the second low crag, which runs along the hill side some way, by well-bedded ash, both fine and coarse (*f*). This ash is considerably altered, and in some parts is quite full of small garnets. Upon the weathered exterior the lines of bedding and, in the coarser parts, the ashy fragments, are plainly seen, but on a freshly fractured surface the latter are found in many places partially to shade into one another, and into the finer matrix. This same ash-bed, a little farther south, is sufficiently cleaved to afford workable slates, and in a small quarry its structure may be well examined, for here both fine and coarsely bedded ash are seen, roughly cleaved across the bedding, and there is some breccia. Fig. 13, Plate II., represents the general microscopic structure of an ash but little altered. It consists of fragments of various sizes and shapes, mingled with some nearly perfect crystals of felspar, and some pseudomorphs after augite, the green crystal in Fig. 13 being an example of the latter. Some of the fragments consist of ash-rock, and others of trap, and between them is much fine powdery material, which appears dark under crossed prisms, with scattered points of light.†

No. 2 forms the upper part of the second low cliff, and is not very much thicker than No. 1, from which it mainly differs in the smaller number of the soft, dark-green spots. Like it also, it is much jointed, and breaks with conchoidal fracture.

Very little of the thin overlying ash (*g*) is exposed about this point, owing to the many fragments of vesicular and compact lava fallen from the crag next above. No. 3, at the base of this crag, is a very compact tabular rock, containing some scattered dark-green pseudomorphs after augite. The microscopic structure of this rock is as follows:—Base for the most part formed of small interlacing acicular felspar prisms, which have a flow round the larger crystals, as seen in Figs. 9, 11, and 12, Plate II. A few grains of magnetite lie scattered about, and a great deal of dirty green and greenish-brown mineral occurs in spots, probably a product of alteration. This widely-diffused mineral seems to be chlorite and chlorophœite, often replacing augite, whether the latter be in small grains or distinct crystals. The few larger—

* The thickness of the beds is in some cases necessarily exaggerated in the section.

† I wish here to acknowledge the kind help I received from Mr. Allport, when first commencing the microscopic examination of these rocks. Also to Mr. Rutley I am indebted for many valuable suggestions.

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though still minute—felspar crystals, are much altered; some of them are replaced by a green mineral, having small, roughly oval, yellowish-brown spots upon its surface, as seen in the uppermost crystal in Fig. 11, Plate II. There are a good many scattered particles of augite, and some serpentinous pseudomorphs, which have rather the appearance of being after olivine. The upper part of this lava is very vesicular, the vesicles being filled with calcite, chalcedony, and chlorite, the latter often lining the walls.

The ash (*h*) is very thin, and of a rough nature. It is succeeded by No. 4, which is about 150 feet thick, and massive, with a curved tabular structure in places, as shown in Fig. 2, Plate VI. This structure is very distinctive of many of these close-grained, compact beds. Lithologically, No. 4 is a grey, close-grained, homogeneous looking rock, breaking off in sharply angular splinters, with oftentimes a fine conchoidal fracture.

When viewed microscopically (Fig. 23, Plate III.), much of the acicular crystalline structure is found to be masked by a great quantity of chlorite diffused throughout the mass, and taking the place of many of the small felspar crystals. There are also many dirty brown and greenish-brown patches scattered about, while magnetite grains and crystals are pretty numerous, and tolerably large. No crystals of any size lie embedded in the base. Probably a great deal of disseminated augite is altered and replaced, the brownish patches possibly representing this mineral.

Having reached the top of No. 4, it will be well for the observer to walk a little southwards to the summit of Falcon Crag. This spot commands a splendid prospect—southwards to the mountains of Borrowdale and Watendlath, westwards across the widest part of Derwentwater to the grassy slopes of Cat Bells and Causey Pike, and northwards over Keswick town to Skiddaw, and down the long reach of Bassenthwaite. The summit shows an ice-worn form, but the ash and breccia rock of which it is composed has become roughened by time. Upon the weathered surface the fragments are easily seen, but many a piece may be broken off, which on the inside scarcely shows any trace of fragmentary structure, but appears quite compact. Just south of the crag there is a deep rocky gully, and crossing the upper part of this is some very well-bedded, fine ash (*i*), having at first sight rather the appearance of the tabular lava, No. 4, and being exceedingly compact within. This is evidently a very fine-grained ash, which has been much altered. On looking down the gully, some of the lines of bedding may be clearly seen, the altered rock being much weathered and bleached.

No. 5, due east of Falcon Crag, is very different from most of the other lavas, being almost wholly vesicular, the vesicles filled with quartz, calcite, or a black earthy mineral (green earth),*

* *Green earth*, it may be noted, is a hydrous product of the decomposition of augite.

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which also lines the quartz and calcite vesicles. A little farther south this bed seems to die away, its place being taken by ash, some of which however is also vesicular.

In order to traverse as complete a section of these rocks as possible, the observer should now walk due south for one third of a mile, upon the same level. He will then take up that part of the line of section in Fig. 2 east of the spot marked "Break," just a little below the craggy lava-beds of Brown Knotts.

The upper part of the bedded ash (*j*) is very well seen at this point; in some places it has a distinctly false-bedded appearance.

No. 6, the basement bed of a very thick series, is a capital example of the lava-like character of these ancient traps. It is not much more than 15 feet thick, and is remarkably vesicular and slaggy-looking at the top, as represented in Fig. 3, Plate VI. It breaks up along irregular and weathered joint-lines, and has an exceedingly lava-like appearance when viewed from a little distance.

Lithologically, the rock is rather different from the preceding traps, being compact, fine-grained, of a greyish-blue colour, with a few *small* felspar crystals embedded and seen only by the light glancing from their cleavage planes. Under the microscope the base is found to be composed of a network of acicular felspar prisms, rather larger than those in the former examples, with dirty-green patches and much yellowish-green and brown mineral occupying the spaces between the crystals. This mineral, evidently a product of alteration, seems to be either chlorite, or a more unstable compound, such as delessite or chlorophœite, which has changed to a brown colour on exposure. Crystals of magnetite are numerous. The felspar crystals, porphyritically imbedded, are mostly triclinic, some however seem to be orthoclase; they occur singly, and in a few scattered groups.* There is not much augite apparent, except in disseminated particles. Some small vesicles occur, lined with calcite and filled at the centre with a black opaque mineral, probably "green earth."

The following is an analysis of this rock:—

Silica	60·718
Alumina	14·894
Lime	6·048
Magnesia	1·909
Potash	2·354
Soda	2·843
Ferrous oxide	6·426
Ferric oxide	1·405
Bisulphide of iron	·395
Phosphoric acid	·281
Sulphuric acid	·103
Carbonic acid	1·660
Loss on ignition	·964
	100·000

* The microscopic structure of this rock is illustrated in my Paper, App. 71.

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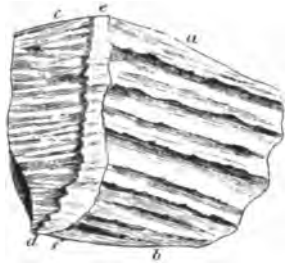

Fig 1. Banded and altered Skiddaw Slate, near the Syenite of Scale Force. Buttermere. (Page 6.)

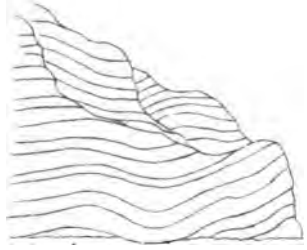

Fig 2. Tabular Lava, No 4 Falcon Crag Series. (Page 15.)

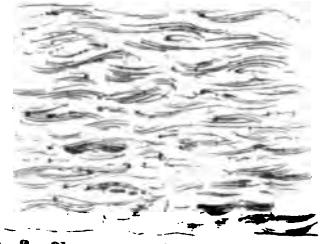

Fig 3. Slaggy top of the Basement-bed of the Brown Knott Lavas. (Page 16.)

Fig 4. Perched blocks at a height of 2000 ft on Glaramara. (Page 87.)

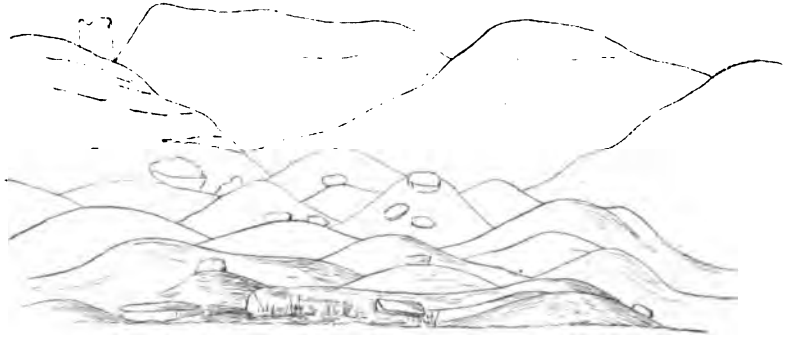

Fig 5. Moraine mounds in the upper part of the Wyth Burn Valley. (Page 88.)

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The slaggy top of this lava passes up into a foot or two of vesicular ash, and this is succeeded by No. 7, which is itself vesicular in many parts and contains some irregular ashy beds of a few inches in thickness.

No. 7 is micro-porphyritic in structure, consisting of a grey base containing some few dark-green spots and a good many small felspar crystals. Microscopically, it consists of interlacing acicular felspar prisms with much green and brownish pseudomorphic mineral in irregular patches, and scattered magnetite grains. Well-formed felspar crystals, porphyritically imbedded, are tolerably numerous, and although much altered they seem to be mostly triclinic. There are also many distinct groups of augite particles, less altered than in the last specimen, and a few small vesicles filled with calcite.

No. 8 is a compact blue rock, also micro-porphyritic in structure and slaggy in its upper portion.

No. 9 is, lithologically, a rock with compact greenish-blue base, containing many soft dark-green spots. Microscopically, it consists of interlacing acicular felspar crystals with irregular greenish patches. There is a sprinkling of magnetite grains. Some of the large felspar crystals are replaced by serpentine, and all seem to be much altered, though traces of triclinic structure are occasionally seen when viewed with crossed prisms. Augite is pretty plentiful, occurring in some very good twin crystals, and there are thin strings of epidote.

No. 10, which cannot be separated from the last by any hard line, though probably belonging to a distinct flow, has a very compact structure; the base is of a greenish-blue colour, and contains many of the soft dark-green spots. Viewed microscopically, it is found to differ considerably from all the lavas before described, inasmuch as the base contains very few acicular crystals, but has more or less of a hazy and indefinite appearance, with numerous specks and patches of a green, pseudomorphic mineral scattered over it, and replacing many of the larger crystals. Under polarized light, the felspar, though much altered and not in great quantity, appears to be triclinic. Augite seems tolerably abundant, and many of the crystals are replaced by serpentine. Both magnetite and pyrites appear to occur. In some parts there is, on crossing the prisms, more or less of the reaction characteristic of a felsitic structure. Garnets also are abundant. Altogether there are many signs of *great* alteration having taken place in this rock.

The bed (*k*), of breccia and ash, is of somewhat irregular thickness and deserves no special notice.

No. 11 is in some parts very compact, but has many vesicular portions. The base is close, of a grey-blue colour, containing some dark-green spots and small filled-up vesicles. A microscopic examination shows it to consist of a mesh-work of acicular felspar prisms, with a good deal of chloritic matter in spots, diffused, and filling vesicles. It contains but little magnetite. What little

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felspar there is in larger crystals is much altered, but some shows the triclinic structure. The augite seems almost wholly replaced.

The ash (*l*) is very well bedded, but south-eastwards of the point where the section crosses, it is rather conglomeratic.

No. 12 forms a very massive rock, and seems pretty constant in character over a large area. In lithological character it is compact, of a green colour with mottled appearance, and contains scattered, soft, dark green spots, and some small felspar crystals. Microscopically examined, the base shows very few acicular prisms, and has a somewhat hazy appearance, with much chlorite disseminated in irregular particles and specks; the same mineral apparently replaces the interior of most of the large felspar crystals, their edges remaining unaltered, and triclinic character generally evident; other pseudomorphs are of serpentine. There is very little augite unaltered, but sufficient to show that with all probability many at least of the smaller chloritic flakes represent that mineral replaced. Magnetite is scarce, or present in very small grains, but pyrites seems to occur in bars and irregular aggregations. The base shows, in places, something of the felsitic structure when viewed with crossed prisms.

In another specimen of this trap examined, taken from a spot (Smaithwaite Banks) about a mile distant, there are, in some parts, a good many acicular felspar prisms, though the base has *generally* a hazy appearance. Some of the less altered felspar shows the triclinic structure, and there seems to be very little unaltered augite. Magnetite is present. Garnets are frequent, together with some small crystals of apatite. There are vesicles filled with quartz, calcite, and chlorite. Yellowish-green veins of epidote traverse some of the pseudomorphic crystals. (Plate II., fig. 11.)

The following is an analysis of No. 12:—

Silica	59·511
Alumina	17·460
Lime	5·376
Magnesia	1·801
Potash	3·705
Soda	3·093
Ferrous oxide	4·926
Ferric oxide	1·271
Bisulphide of iron	·604
Phosphoric acid	·115
Sulphuric acid	·086
Carbonic acid	1·569
Loss in ignition	·483
	100·000

The beds of ash and breccia (*m*) which overlie the last described lava-bed, and range upwards to the summit of Bleaberry Fell, are in various stages of alteration. In some cases, while the fragments are clearly discernible on the outside, a freshly fractured surface has a very trap-like appearance, and upon the summit of the Fell it is sometimes very difficult to say what is of the nature of ash and what is not.

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A microscopic examination of one of the most trap-like pieces, taken from amidst the more evident ash on the Fell top, reveals a very decided difference in structure from that of the lava-flows already described. Thus, the specimen examined, with (lithologically) a mottled appearance somewhat similar to that of the last described lava, has (microscopically) a decidedly granular base quite comparable in structure to the finer matrix of some of the less altered ash, and, like it, appears dark, with scattered points of light, under crossed prisms. There are fragments of both plagioclase and orthoclase felspar, some of the latter being fairly perfect twins, but all being highly altered. There are also cavities filled with chlorite and other products of alteration, and cracks, with a brown mineral. None of the acicular crystals occur, so common in most of the lava-beds, neither is there any decided evidence of the presence of magnetite.

This completes the detailed account of a good typical section of ashes and lavas, as shown in Plate V. It now remains to point out any striking deviations from the above general characters, and to treat of one special group of highly altered ashes which closely resemble true felstones in their general appearance.

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CHAPTER V.

DESCRIPTION OF THE ROCKS—*continued.*

2. Volcanic Series of Borrowdale—*continued.*

Although the examples of contemporaneous trap met with in the typical section represent the general character of these rocks, a few other instances must be given in order to render the account somewhat more complete.

(b.) *Variations among the Lavas.*

On Eycott Hill (often called Berrier Nittles), in the north-east corner of the map, there is a fine series of lava-flows of varied character. One of the most marked is a handsome porphyritic rock, with crystals of felspar, sometimes more than an inch long. These crystals consist of plagioclase, and contain glass-cavities and magnetite grains, together with many enclosed portions of the base, which is made up of the usual network of acicular felspar prisms with intervals filled by chlorite and magnetite.* There are some well defined crystals of augite, the twin shown in Fig. 10, Plate II., under polarized light, being an example; this crystal contains glass-cavities, one of which is circular, and the $\frac{9}{10000}$th of an inch in diameter, it contains a bubble—caused by the shrinking of the glass on cooling—the $\frac{1}{5000}$th inch in diameter, and two small magnetite squares measuring respectively the $\frac{1}{10000}$th and the $\frac{1}{40000}$th of an inch. There occur also some chloritic pseudomorphs, some of which are almost certainly after olivine. Under crossed prisms there is no absolute darkness indicating any *glassy* base, the felspar remaining more or less transparent, and the dirty-green pseudomorphic mineral being only partially dark where thickest.

The following is a description of the structure of another rock from the same hill. Lithologically it consists of a compact black or blue-black base with the cleaved faces of minute felspar crystals sparkling in it here and there. Examined microscopically, the base is found to consist of a very great number of minute magnetite grains and crystals, giving quite a dark spotted character to the section; mingled with them are acicular felspar prisms. Much chloritic matter occurs diffused and in veins. The embedded felspar crystals often contain parts of the base enclosed within them, and portions of their outline are very indistinct, with margins frequently indented by the base running far into the crystals. They show the banded triclinic structure remarkably well in polarized light, as in Fig. 12, Plate II., where a representation of the frequent flow of the acicular prisms around the large crystals is attempted; the very dark appearance of the base in this figure is

* As in other cases, much of the diffused green and brownish mineral in the base is probably Delessite or chlorophœite.

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mostly due to the innumerable magnetite grains. There is very little unaltered augite, and there appear to be a few hexagonal crystals of apatite, with some rather doubtful pseudomorphs after olivine.

In this series of lavas there are also some highly vesicular, with the vesicles drawn out most markedly along the line of flow, and filled with chlorite, chalcedony, and calcite. The base, in such cases, consists of numerous acicular felspar prisms, with many magnetite grains, and much disseminated chlorite.

Just above a farmhouse called Stanah, at the upper end of St. John's Valley, is a lava-bed of very distinctive character, which, though massive, is of no great thickness. Lithologically, it consists of a very compact base with crystals of augite, many of which are one fifth of an inch in length, replaced by a soft dark-green mineral, probably chlorite. Microscopically, the base consists of many acicular felspar prisms mingled with granules and patches of a yellowish-green and brown mineral, chlorite and its ally chlorophœite (?). Some of the augite is but little altered, with glass-cavities containing magnetite crystals, and often showing the banded structure parallel to the crystal sides which is so frequently seen in the augite of the modern Vesuvian lavas.

In Fig. 9, Plate II., is shown the structure of a thick, massive lava-bed, upon the east side of Scarf Gap. In many parts the rock has the curving tabular form described and figured as occurring in No. 4, of the Falcon Crag series. It has a compact, greenish-blue base, with scattered dark-green spots. This base consists of interlacing acicular prisms, with numerous minute grains of magnetite and some tolerably large crystals of the same or of pyrites. The acicular structure is much obscured in many parts by alteration and the presence of diffused chlorite. There are also numerous small pieces of augite but little altered, and some large crystals, a part of one of which is seen in the lower half of the figure. The large portion in the upper half of the figure is part of a pseudomorph after felspar, and the difference between the two is rendered very evident in polarized light. The augite crystals enclose grains of magnetite. In many parts there is a distinct flow of the small prisms around the larger crystals.

A very compact bed of lava, occurring quite at the foot of Grange Crags, and of the crags just behind Lowdore Hotel, presents a finely crystalline base, which is wholly made up of small felspar needles, averaging the $\frac{1}{175}$th of an inch in length and the $\frac{1}{1750}$th in breadth, all lying parallel to one another, with a little green chloritic matter about and between them. There are also grains of magnetite, and a few small specks of unaltered augite, but no large porphyritically imbedded crystals of any kind. It is sometimes very difficult to distinguish, *in the field*, between a contemporaneous trap, such as this, and some of the fine but unbedded ashes, though the microscope at once reveals the difference.

It will be seen from the description of the microscopic structure of the many different examples of old lava-flows given above, and from the analyses of two of them differing somewhat in character,

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that these rocks occupy a position somewhat intermediate between the basic and acidic groups. They contain less silica than do most members of the latter class of rocks and more than most members of the former.* The per-centage of lime is more than that of the acidic group, and the per-centage of ferrous and ferric oxides markedly less than what occurs among the basic group.

If we compare these old lava-beds with those of almost identical age in Wales, the difference is found to be very marked both in internal structure and chemical composition. The Cumberland lavas are essentially doleritic; among a mesh-work of acicular felspar crystals there occur crystals of magnetite, augite, and triclinic felspar, though in some cases the crystalline base passes into one of a *somewhat hazy* and felsitic character. The Welsh lavas (felstones) have *generally* a markedly felsitic base, showing a hazy or milky ground and, when viewed with polarized light, breaking up into a coloured breccia.†

Taking these various facts into consideration, it would seem that the Cumberland lavas form a group intermediate between the Dolerites and the Felstones, though more closely allied to the former than to the latter.‡ It may perhaps seem that this deduction is too large considering it is partly founded upon so small a number of analyses, but the *general* uniformity in appearance of the undoubted lavas is so striking as to give me considerable confidence in the above analyses as representing the average chemical composition of the *group*. A multiplication of such analyses in future may tend to confirm this point. The term Felsi-dolerite, proposed in the paper referred to in the foot-note, I would regard as merely temporary, until, in the course of time, our knowledge of rock classification should so far have increased as to render the application of *definite* names a safe and sure process.

(c.) *Variations among the Ashes.*

The section, Plate V., that has been examined somewhat in detail, while giving the best general idea of the old lavas of the district, fails fully to represent the ashes. The purple breccia at the base is indeed as typical a purple breccia as any, but the ash-beds in general along this line are not strongly developed.

Breccias occur of all degrees of coarseness, from rocks in which the fragments are an inch in diameter to those in which the component blocks are several yards across, as is the case near Sourmilk Gill, a little north-east of Base Brown. Generally the fragments are angular, or at least not *waterworn*; but *occasionally* these

* See Table of Analyses of Rocks, by Roth, and Tables of Rock Analysis in Cotta, "Rocks Classified and Arranged," p. 85; also Manual of Geology, by Jukes and Geikie.

† For a comparison of the volcanic products of Wales and Cumberland with each other and those of Vesuvius, &c., see the author's memoir, entitled "Notes on the Microscopic Structure of some Ancient and Modern Volcanic Rocks." *Quart. Journ. Geol Soc.*, Vol. XXXI. p. 388. I have recently examined some Welsh lavas showing a minutely crystalline microscopic structure.

‡ Some of the Eycott Hill lavas are fair dolerites and basalts, and the analysis of *some* of these would probably show a chemical composition more nearly corresponding to that of the basic group than do the analyses furnished in these pages.

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coarse deposits are truly conglomeratic, that is to say, they are made up of stones, which have been more or less rounded in connexion with their stratification. One instance, south-east of Bleaberry Fell, has already been mentioned. Another occurs at the foot of High Rigg, just south of Sikes and west of the chapel of St. John's in the Vale; this conglomerate is probably not far removed from the base of the volcanic series. A third example, though outside the immediate limits of our present district, must be referred to. It occurs at Caple Crag, south of Latterbarrow, in Sheet 73 (6-inch); where an ash and trap conglomerate contains many rolled pebbles of the Skiddaw Slate grit occurring on Latterbarrow; all the pebbles, some of which are of a considerable size, lie with their longer axes parallel to the bedding planes of some overlying ash. Another good example of a conglomeratic ash may be seen in an immense *boulder* lying behind Lyzwick Hall upon the lower slopes of Dodd (Skiddaw Slate), beneath Skiddaw. In some of the cases of finer breccia, or coarse ash, the fragments lie markedly with their long axes in planes, answering to those of bedding; and it frequently happens that thin beds of well stratified ash alternate with those of breccia and coarse ash. The fragments composing a breccia or coarse ash consist, of well-bedded ash, very often, however, highly altered; of coarse ash; of traps; and occasionally of Skiddaw slate in some form, generally much metamorphosed.

The ash varies from a rock containing fragments of the size of walnuts, which is generally marked on the 6-inch maps as "very coarse ash," to a rock made up of the very finest possible powder, such as that beneath which Pompeii was buried. Very generally it is more or less stratified, especially the finer kinds, but there also occur great thicknesses of coarse and rough ash quite unbedded, or with lines of bedding very few and far between, and sometimes even the finer ash is not much stratified. The coarser kinds, where bedded, are often, but not always, very irregularly so, some layers thinning out and others thickening. Occasionally, also, a very decided false-bedding is seen among the finer varieties. The fineness of bedding however is very striking in some cases, so that when the rock is much jointed and weathered, the blocks lie upon the mountain side like scattered piles of books, as may be well seen upon Whelp Side, part of the western flank of Helvellyn. The weathering along these fine lines of bedding is often very marked, some of the layers standing out in wonderful relief and producing effects of the most delicate carving.

Over large tracts in certain districts, as south of Mell Fell, and much of the northern part of the Helvellyn range, the ash is fine, felspathic, and but little stratified, so that when much compressed and altered there is very little to distinguish it from felstone, unless it be the traces of fragments upon some of the weathered surfaces.

Cleaved ash.—Such felspathic ash, as that just described, is generally much cleaved, seldom however producing good slates. For though the various beds of volcanic ash are generally more

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or less affected by slaty cleavage; it is only in a few parts, comparatively, that good workable slate occurs. Of course, as a general rule, the fine deposits are more perfectly cleaved than the coarse, but in Borrowdale and some other spots, breccias afford rather thick but workable slates, and in many cases the flattening of the fragments between the planes of cleavage, and the lengthening of them in the direction of the cleavage-dip, is clearly seen.* In the finer varieties of slate, since the cleavage usually crosses the bedding at a somewhat high angle over most of the district, the lines of bedding are often beautifully shown upon the cleavage-planes marked by bands of different colour and degrees of fineness, with small faults occasionally shifting them, and producing true and admirable geological diagrams. In most slate quarries, the less perfectly cleaved ash affords thick and rather slabby pieces much used for building purposes, but this volcanic series seldom yields any building stone capable of being squared nicely or used in large blocks. The thicker fragments thus used in building, are placed horizontally one above the other, and generally without any mortar on the outside.† The *large* flaggy pieces of slate are frequently used for gate-posts; and occasionally, the thinner specimens are placed edge to edge for field or garden fences.

Concretionary Ash.—Many of the beds of ash, especially when much altered, are full of concretions of all sizes. An excellent example occurs on either side of Grisedale Hause (Helvellyn range), where the structure is associated with a semi-columnar appearance, while at the same time the lines of bedding are clearly seen, and the boundaries of the concretions cut through some of the larger ashy fragments. In some of the highly altered, flint-like, fine ashes of the Scafell Pikes range, this structure is developed to an extraordinary extent, and sometimes the concretions take a more or less oval form along the lines of bedding.

Volcanic Bombs.—Distinct from the concretions just mentioned are true volcanic bombs, which occasionally occur embedded in the ash. They are of globular form and often contain a hollow in the centre lined with quartz, and having clear quartz and other crystals pointing inwards.

Most of the rocks of this series, whether ash or trap, yield abundant material for wall-making and road-mending.

(d.) *Highly altered Ash-rocks.*

The alteration of ash-beds in some parts of the Falcon Crag series has already been noted, but the amount of change effected in that case is slight in comparison with what occurs in many other parts of the district. By the mere examination of hand specimens I am convinced no one could in all, or even in most

* App. 25 and 36.

† Those houses built of such material seem to be the driest, in which the oblong flat stones have been placed not quite horizontally, but sloping a little outwards; example, the Borrowdale Hotel.

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cases, distinguish between an ash, highly altered, and a trap, especially felstone-trap, and it is only by working over large tracts, tracing out every separate bed and mapping all well-marked lines, keeping at the same time a sharp look-out for any indications of fragmentary structure, that anything like a true idea, in many instances, of what is trap and what is only highly altered trap-like ash can be gained. Hence I shall be very much surprised if my mapping of many parts of the district be not severely criticised and found fault with by those who examine only one small area and do not take into consideration all the facts gathered together, during the course of several years, from every mountain flank and summit.

It is possible to collect a most complete series of specimens, from the ash, comparatively little altered, in which each separate fragment can be clearly seen, to the most compact, trap-like and even columnar felstone. A few words on the reasons which have led me to map considerable tracts of very felstone-like rock, as altered ash, may not here be out of place.

The first beds of contemporaneous trap (lava) mapped, were those belonging to the Falcon Crag series near Keswick, described in detail in the former pages. These, being for the most part of a very unmistakeable character, served as examples of typical lava-beds as distinguished from typical ash. Subsequently, as the work became extended, a new set of rocks was met with, which was unlike the typical lavas in many respects though often very like some of the felstones of Wales, but yet always passed gradually into undoubted ash and presented, every here and there, indications of fragments and traces of apparent bedding. Moreover there was something in the colour and occasionally burnt or porcelainic appearance of these rocks that led me from the very first to associate them with metamorphic action, and, while separating them from the ordinary ash, as far as possible, by lines which were always dotted or uncertain, to recognise them as something distinct from the first-mapped contemporaneous traps. As lines were traced south-westwards towards Wastdale, the band of doubtful rocks was found to occupy a constantly increasing area and to acquire an even more felstone-like nature in many parts, and then the rocks of Scafell and the districts immediately adjoining the Eskdale granite and part of the Ennerdale syenitic granite were found to be of the same nature. Over such areas of felstone-like rock, while the internal appearance is always pretty much the same—that of a compact blue felstone, often becoming porphyritic near the granite—the external appearance is varied; in some cases the exterior is marked by streaky lines more or less resembling bedding; in other cases, distinct lines of different colours are seen running all strictly parallel to one another and in *every* respect like lines of bedding; while in others again, well-marked fragments are discernible on the outside, with streaky lines more or less bending round them, or the streaky appearance is combined with a truly bedded one.

In the light of these facts it seemed reasonable to conclude

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that the doubtful rocks were merely highly altered ashes, the zone of alteration roughly corresponding with the strike of the beds because the altering cause beneath may have had a similar general direction. The continued discovery of rocks of similar nature in various parts of the district, over small areas, and quite unlike any regular bands of trap, still further confirmed these conclusions, and lately, further help has been given by the use of the microscope. The contemporaneous traps were examined and found to be of the basaltic type, while the doubtful rocks showed quite a different structure. A comparison was then made between the volcanic rocks of Cumberland and those of Wales, when it was seen that in the first place the undoubted contemporaneous traps of Cumberland were distinct altogether from those of Wales, the latter being true felstones, and the former rather basaltic than truly felsitic; and in the second place that though in many outward respects the doubtful rocks of Cumberland resembled the Welsh felstones, yet were *most* of them distinct in their inner and minute structure, although *some* could not even be distinguished microscopically from the true traps of the Arans and Snowdon. When however the ashes of Wales were examined in like manner, the further fact was revealed that many of the *evidently* altered felspathic ashes of Wales had the *same* microscopic structure as the associated felstones, *provided* the ash was of a fine texture, which was frequently shown by the lines of bedding on the weathered exterior. Hence the resemblance in microscopic structure of *some* of the Cumberland doubtful rocks to the Welsh felstones might only be a resemblance similar to that of the highly altered ashes of Wales to those same Welsh felstones.* So that altogether the microscopic observations tend to confirm in quite an unexpected manner the somewhat difficult and obscure mapping of previous years. A few examples will now be given of the microscopic structure of some of these highly altered ashes.

To aid me in coming to a right conclusion, I examined microscopically some highly altered and almost felstone-like slate from beneath the intrusive sheet of greenstone of Craig Wen, near Capel Curig. The base was found to consist of an immense number of very minute granules with some opaque spots caused by their closer aggregation. Under polarized light, with crossed prisms, the ground was dark, with many scattered points of light. The finer parts of ash, but little altered, showed exactly the same granular structure. Hence these cases became examples of a structure, having a mechanical origin, with which that of the supposed more highly altered ashes might be compared.

In Fig. 14, Plate II., is represented the microscopic appearance of a highly altered, somewhat coarse ash, the part seen in the figure being some of the finer matrix between the fragments. The rock itself is exceedingly compact and trap-like, only that on the

* Care has of course been taken to distinguish between highly altered and bedded, fine ash, and *finely streaky*, contemporaneous felstone.

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weathered exterior the outlines of fragments are in many cases *plainly* discernible. Its fragmentary nature is also well seen in the thin slice when examined with a pocket lens. Under a high power the fine matrix appears decidedly granular, the granules however being frequently collected along lines which flow round and among the separate fragments, and being mainly composed of green chloritic matter, which also appears to have replaced some of the crystalline fragments. I think there can be but little doubt, in this case, that the granular chloritic *flow* has been produced subsequently to the formation of the rock, by the same cause that converted a mass of separate fragments into a compact trap-like bed, in which not a trace of fragmentary structure can be detected upon a freshly fractured *inner* surface.

Figs. 15 and 16 represent another case, in which, however, the original ash was probably very fine. Viewing the rock where best developed, upon Base Brown in Borrowdale, one could have no doubt whatever of its true felstone character, seeing that it is compact, blue in colour, weathering white round the edges, having streaky lines on the outer surface, and withal decidedly columnar. Yet the microscope at once confirms the suspicions at first entertained as to its being a true contemporaneous felstone, for when viewed with a high power there is absolutely no difference between the granular *structure* of its base and that of the Welsh slate-rock mentioned above. In parts, also, the granules, which seem to be mostly chloritic, have been collected along patches and in streaks, and these streaky lines have a decided flow around some of the small fragments, all of which seem highly altered. With crossed prisms, the base also appears like that of the Welsh slate under similar circumstances, viz., dark, with scattered points of light (Fig. 16). In Fig. 15 the clear spaces above are quartz, and below there is a fragment of felspar. In this case, the flow of the matrix, as seen inside the rock, is accompanied by apparent streaky lines of flow outside, exactly answering, indeed, to the banded lines in the altered slate around the Ennerdale syenitic granite, described on page 6. Hence it seems only right to conclude that the original rock has been so far altered as to cause the development of a great number of chloritic particles, and a flow to take place among them in the direction of least resistance, which in many cases would correspond to that of the original bedding.* Since making the above examination I have found a columnar, felstone-like rock, upon Great End, similar in all respects, only that in this case, most distinct, fine lines of bedding, can be traced on the weathered exterior all round the columns.

Beneath, are analyses—of the rock from Base Brown, two miles from the granite of Wastdale Head; of a highly altered *coarse* ash from Slight Side, about a mile from the granite (in the one-inch sheet 98 S.W.); of a probable contemporaneous

* These chloritic particles may represent some of the original rock-grains altered into or replaced by chlorite, or they may have no *direct* relation to the original particles, except that the mineral is the result of chemical changes which have taken place in the rock as a whole.

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trap, very highly altered, *close* to the granite of Lingmell Beck, Wastdale Head; and for comparison, I add that of a Welsh felstone, from Aran Mowddwy.

	Base Brown.	Slight Side.	Lingmell Beck.	Aran Mowddwy.
Silica	69·673	68·421	59·151	83·802
Alumina	19·492	15·855	19·212	7·686
Lime	2·296	2·016	5·208	·896
Magnesia	·324	·792	1·909	·109
Potash	4·554	3·338	2·933	2·161
Soda	3·017	5·627	4·217	4·229
Ferrous oxide	2·784	2·855	5·192	·408
Ferric oxide	·442	·172	·879	·111
Bisulphide of iron	·410	—	·360	·191
Phosphoric acid	·343	·204	·439	·089
Sulphuric acid	·205	—	trace	·017
Carbonic acid	·660	trace	trace	trace
Loss on ignition	·800	·720	·500	·301
	100·000	100·000	100·000	100·000

If these analyses be compared with those previously given on pages 16 and 18, it will be seen that the Base Brown and Slight Side rocks hold, chemically, an intermediate position between the undoubted Cumberland lavas and the Welsh felstones, while the analysis of the metamorphosed contemporaneous trap from Lingmell Beck, corresponds almost exactly with those of the lava-beds already given. It is also very satisfactory to find that the analyses of two specimens of ash should so closely agree with one another, though highly altered, taken from spots more than four miles apart, and the one representing a fine and the other a coarse ash. It may, at first sight, seem strange that the chemical composition of the ash and lava-beds should not more closely agree, especially *if* both were erupted at the *same period* and from the *same vent*, but this may not have been the case in these instances, and when it is considered that the lighter constituents of the volcanic matter would be more likely to be thrown or carried to a distance than the heavier, it is not surprising to find that the difference in composition is just what would be caused by the absence from the ash of a large proportion of augite and magnetite, both considerably heavier than the felspar.*

Then there are other examples of rocks, which must certainly be included under the same class, presenting internally quite the felsitic structure—a hazy or milky-looking base with scattered particles upon it—and under crossed prisms, giving the peculiar coloured-breccia reaction. Sometimes such are evidently due to the alteration of masses of unbedded or but poorly bedded ash; in other cases to a similar alteration of extremely fine-bedded volcanic dust; but in both instances traces of fragments or bedding, or the

* I am not aware whether chemical analysis has shown a like difference to prevail between the ash falling at a distance from a modern volcanic vent and the lava flowing from the same, but I believe the requisite examination has never been made.

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passage gradually into a decidedly bedded or fragmentary rock, will show what was probably the original structure. Of course, each of these last three tests might in itself be inconclusive, since a true trap rock *may* sometimes include fragments, *may* have thin layers of bedded ash interwoven between two flows, or *may* dovetail gradually into, or end rather abruptly against, true ash deposits. Such cases, however, are recognizable enough among the undoubted traps and but little altered ashes, and there is seldom much hesitation in drawing the parting line between two such deposits; very different from the uncertain and gradual passage of highly altered into less altered ash. One may examine, in succession, under the microscope, a true felstone from the Arans or Snowdon, well bedded but highly altered ash from above Glaslyn, Snowdon, and highly altered felspathic ash from Cumberland, and careful drawings made of the structure of any one of them might answer equally well to illustrate that of the others.

It will be readily understood that, in the event of thin or even thick beds of true contemporaneous trap occurring in the midst of these highly altered rocks, it would be almost impossible to detect them, or if they were detected, to trace them across the country.

It is satisfactory to know that difficulties of quite a similar nature were met with in the mapping of the Welsh volcanic rocks, and Mr. Aveline and others, in the more southern part of the lake-district, also agree that "the altered ash or breccia is with difficulty distinguishable from a lava. . . . . When these beds approach the Shap granite, they are altered into a dark coloured hard porcellanous rock."*

The late Prof. Sedgwick, whose papers on the geology of this district must impress all who read them with the thoroughness of his observation, had his attention frequently attracted by the puzzling nature of many of these rocks. Thus, in one of his letters on the Geology of the Lake District (dated 1842), he says:—

"When I began, 20 years since, to examine the lake country, I believed in the igneous origin of basaltic and porphyritic rocks; but I was staggered in my creed, and filled with astonishment, almost at every step, when I saw the alternating masses of slate and porphyry, and the way in which they were blended together. The Wernerian hypothesis has now passed away, and has been extinguished by the more mature discoveries of an advancing science; but it lent itself readily to the explanation of many perplexing facts, and had the merit, at first sight, of great simplicity; and I may venture to affirm, that no one is prepared to understand it, or to do any justice to its author, who has not studied, in the field, such phenomena as are continually offered by the Cumbrian slates."†

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* Explanation of Quarter-Sheet 98 N.E., p. 4. † App. 21.

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CHAPTER VI.

DESCRIPTION OF THE ROCKS—*continued.*

Igneous Rocks.

Following out the previous plan, the various classes of igneous rocks will now be described, their physical history being left for another chapter.

(a.) *Granites, Hornblendic Granites, Quartz Felsites, and Felstones.*

Skiddaw Granite.—Only a very small area of granite comes into the area of 101 S.E. It is seen in the course of Sinen Gill, between Skiddaw and Blencathra, and is doubtless connected beneath with the larger mass in the valley of the Caldew, a mile and a half to the north.

It consists of a white felspar, dark mica, and interstitial quartz. A microscopic examination shows the mica to be for the most part brown. The felspar is partly orthoclase, which shows the dark, banded structure described by Prof. Hull in his paper on the granite of Firbogh, caused by lines of exceedingly minute cavities;* but a great deal is triclinic, showing the characteristic coloured banding under polarized light.

The quartz, as usual in granites, consists of many separate portions meeting one another, and these are often edged by fine-coloured bands when viewed with the polariscope. It contains numerous liquid-cavities with moving vacuities, and some rather stout long crystals (belonites), as well as fine hair-like bodies (trichites).

There are a few magnetite grains associated with the mica and felspar. In some slices examined there likewise occur small patches of serpentine, exhibiting in polarised light its characteristic mottled or brecciated appearance of neutral tint shades.

The following is an analysis of this granite:—

Silica	75·223
Alumina	11·140
Lime	1·624
Magnesia	1·081
Potash	4·516
Soda	3·996
Ferrous oxide	1·771
Ferric oxide	trace.
Phosphoric acid	·149
Sulphuric acid	trace.
Carbonic acid	trace.
Carbonaceous matter	·103
Water	·397
	100·000

* "Observations on the Microscopic Structure of Irish Granite (No. 1)," *Geol. Mag.*, vol. x. p. 193.

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Wastdale Granite.—None of the Wastdale or Eskdale granite comes properly into this area, but as it approaches very near to the southern margin of 101 S.E., a word must be said about it. At Wastdale Head it occurs over a small tract at the foot of Kirk Fell and Lingmell, probably connected with the main mass of Eskdale granite, along the axis of Wastwater. The prevailing tint of the rock is reddish, from the colour of the felspar, and the mica is dark. In the slices examined microscopically, there are both orthoclase and a triclinic felspar, and the mica appears dark-brown. The quartz contains many cavities much collected along lines.

This Wastdale Head granite sends off quartz felsite (elvanite) * dykes, one of which strikes northwards, across Kirk Fell, and is pretty similar in composition to the granite, minus the mica. This dyke is well cleaved upon Kirk Fell summit, the surrounding altered ash-rock not being so.

The following is an analysis of the Eskdale granite, the specimen being taken from near the edge, just south of Great How (in 98 S.W.):—

Silica	73·573
Alumina	13·750
Lime	1·064
Magnesia	·396
Potash	3·512
Soda	4·315
Ferrous oxide	2·103
Ferric oxide	·615
Phosphoric acid	·012
Sulphuric acid	—
Carbonic acid	trace.
Water (loss on ignition)	·660
	100·000

Ennerdale Syenitic Granite.†—This rock, though occupying a large area, is tolerably uniform in its appearance. For the most part it is red, due to the colour of the felspar, modified however by the few dark specks of hornblende (?) and occasionally mica, and the transparent colourless quartz. Generally the rock is of tolerably coarse grain, and the hornblende is wanting or small in quantity, but occasionally it loses its usual red colour and assumes a more sombre and grey hue, from the increased quantity of hornblende (or a chloritic mineral), and mica, and less decided colour of the felspar; in such cases it is usually more fine-grained. It frequently crumbles away on the mountain-tops to a sandy deposit, in which the irregularly shaped angular particles vary in size from that of peas to small shot; this may be well seen over the ground west of the summit of Red Pike. The microscopic structure of several samples of this rock will now be described.

No. 1 (Fig. 6, Plate I.).—This is an example of red syenitic granite with but little hornblende, and of a medium coarseness of grain.

* I use this term instead of the old form "Quartziferous Porphyry;" the dykes correspond to the Cornish elvans.

† Hitherto this rock has been called "syenite;" although hornblendic in parts, it is probably more entitled to the name of "Chloritic" than of "Hornblendic (Syenitic) Granite."

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The felspar, which occurs largely in rather short and wide crystals, has, in great part, a very striated and reticulated appearance (see Fig. 6) caused, it would appear, by the presence of innumerable very minute cavities, often arranged along somewhat irregular lines. It is a good deal altered, but both plagioclase and orthoclase are present, the former being the most abundant. The scattered particles of a soft, green (chloritic) mineral, often taken for hornblende—and perhaps representing it—are neither very numerous nor of defined form. The quartz is interstitial,* and includes many liquid-cavities with moving bubbles, the cavities being often arranged along lines, as in the large piece of quartz in Fig. 6; it also contains glass and some stone-cavities, acicular crystals, and occasionally small magnetite grains. Magnetite occurs pretty plentifully throughout the rock in some parts, but is nearly absent in others.

The analysis given below is that of a specimen having the most general characters of the rock, from near Scale Force, Buttermere:—

Silica	71·442
Alumina	15·340
Lime	1·064
Magnesia	·720
Potash	4·439
Soda	3·951
Ferrous oxide	1·107
Ferric oxide	1·230
Phosphoric acid	·118
Sulphuric acid	trace.
Carbonic acid	trace.
Loss on ignition	·589
	100·000

No. 2.—One of the fine-grained grey specimens, with much altered hornblende (or a chloritic mineral), and little quartz.

The felspar is a great deal altered, though there is evidently both orthoclase and plagioclase present.

There are many long prismatic crystals, some of which are green, but others appear colourless and broken, with the parts only just separated from each other. A great deal of the green mineral is of secondary formation and seems sometimes to fill cavities.

The quartz is sparingly developed, occasionally filling up the interstices between the other minerals. It contains cavities as in the previous case, and also some of the clear prismatic crystals and needles. A great many irregular black masses are scattered about, often in connection with the green mineral, these may sometimes be due to collections of grains of magnetite, but are probably more often a direct product of alteration, similar to the peroxidation of the iron in chlorophœite, which in many respects the green mineral resembles.

* The quartz may be said to be *interstitial* when it seems merely to fill up the interstices between the other minerals, and not to assume a crystalline form.

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No. 3.—This is a specimen taken from the very edge of the syenitic granite, at its junction with ash, which is highly altered. The rock lithologically resembles a felstone, in which are numerous aggregations and nests of hornblende, giving it a black spotty appearance.

Under the microscope the base has much of the white milky appearance of felstone, and under crossed prisms, shows somewhat imperfectly the felsitic reaction. Scattered over this base are numerous granular particles and collections of small hornblende crystals, distinctly dichroic. There are also grains of magnetite, frequently grouped together. This rock might be called a hornblendic felsite.

Sale Fell Minette (Fig. 17, Plate III.).—This is a very small patch on the northern edge of 101 S.E., just above Wythop Vale, west of Bassenthwaite Lake. It is, however, a rock unlike any other in the neighbourhood. In a pink felspathic base is scattered an abundant supply of dark, greenish mica.

The felspathic base (Fig. 17, Plate III.) is decidedly crystalline, orthoclase being most abundant, but a triclinic felspar also present.* The mica is green (probably biotite), and the quartz is present in small quantity, being interstitial and containing many cavities. Long acicular prisms are pretty plentiful, and they sometimes project into or cross the quartz.

This rock differs *mainly* from the true granites in the comparative absence of quartz, what little there is indeed, being invisible to the naked eye, and of secondary origin.

Mica Trap of Dodd.—Several dykes traversing Dodd (Skiddaw) should probably be classed under the head of mica-traps. The rock is much altered but consists essentially of felspar and mica, and some quartz not visible to the unassisted eye. The felspar is all much changed. There may be a little hornblende, and calcspar occurs, filling cavities.

St. John's Quartz Felsite (Fig. 5, Plate I.).—This is very different in its general appearance from the Ennerdale syenitic granite. It is of various shades of colour, from red, through bluish-grey, to almost white; and consists of a felspathic base containing crystals of felspar and quartz, together with a little disseminated magnesia-mica and perhaps some altered hornblende. Some of the felspar, probably that which is oligoclase, is much altered into a soft, light-green, steatitic mineral.

The general microscopic character is represented in Fig. 5, Plate I., where the brownish base and crystals are felspar; the green, for the most part, mica; and the white squarish spaces, various sections of quartz crystals.

The felspar is mostly orthoclase, though some triclinic,—probably oligoclase—is present. It forms a more or less crystalline base in which the quartz is embedded.

The quartz differs markedly from that in the Ennerdale rock,

* The very small portion of the base seen in the figure does not fairly represent its generally crystalline character. The white space is quartz, and the green, mica.

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inasmuch as it is crystallized instead of being merely interstitial. It contains many minute liquid-cavities and some small prismatic crystals. Magnetite grains are occasionally pretty frequent.

Armboth and Helvellyn Dyke (Fig. 4, Plate I.).—This beautiful dyke, though not traceable quite up to the St. John's quartz-felsite, is evidently, from its structure, closely allied to it.

Although quite narrow, generally 20 to 30 feet wide, it retains the same characters over long distances. In a dull red felspathic base are numerous crystals of pink felspar and quartz, together with sparsely scattered green mica, and some of the same soft, steatitic-looking mineral as in the St. John's quartz-felsite.

Its microscopic structure is shown in Fig. 4, Plate I., where the large white spaces are sections of quartz crystals imbedded in the brown felspathic base, and the green is mica.

Both orthoclase and triclinic (probably oligoclase) felspar are present, some of the latter in conspicuous crystals; and the base is confusedly crystalline.

The quartz occurs in two forms, *generally* crystallised, but occasionally interstitial. The crystals, as will be seen on comparing Figs. 4 and 5, are much larger than in the St. John's rock and present beautiful microscopic objects, since they are full of liquid-cavities, containing bubbles, the cavities being frequently arranged along lines (see Fig. 4). The crystals occasionally wrap round and enclose portions of the base.

The following is an analysis of a typical specimen of this rock:—

Silica	67·180
Alumina	16·650
Lime	2·352
Magnesia	1·549
Potash	2·914
Soda	4·032
Ferrous oxide	2·151
Ferric oxide	·559
Phosphoric acid	·179
Sulphuric acid	trace.
Carbonic acid	·885
Carbonaceous matter	·797
Water	·752
	100·000

Felstones. There are a few dykes and small intrusive masses which may be classed under this head. Of such is the dyke ranging from White Pike, east of Clough Head, and crossing part of Matterdale Common. It is probably in connection with the St. John's quartz felsite, but in its eastward range is a hard, white-looking, felsitic rock, containing a good deal of iron pyrites. At White Pike, its structure is quite similar to that of several small masses occurring among the altered Skiddaw slate, near the quartz felsite, and in some places there appears to be a passage from the slate into this imperfectly developed quartz felsite.

Banded Felstone Dykes.—These occur on the slopes south-west of Buttermere, on the Mosedale Red Pike, and are very numerous

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north of Wastwater. They are quite narrow and show parallel and contorted lines; these lines have relation to the dyke walls, and are therefore frequently nearly vertical.

The following is the microscopic structure of one of the best developed of these dykes.

In plain light the base has a felsitic appearance, with bands of a smooth, burnt-sienna colour, and a good many small, irregularly shaped pieces of a green and slightly dichroic mineral. Under crossed prisms the brown parts appear dark, but intersected by cracks and irregular channels, while the intermediate bands show the felsitic reaction, and a good deal of free quartz is seen to be collected along lines. The green mineral is epidote, and shows bright colours. A little calcspar also occurs, with its two sets of cleavage planes very clearly seen, and apparently filling cavities.

(b.) *Diorites.*

In connection with the Skiddaw Slates and Volcanic Series are many small bosses and dykes of intrusive rock. It is generally quite impossible to distinguish in the field between those that are Dioritic and those that are Doleritic, especially as their development is small, and they are much altered. The outer portions of many of these masses have often a very different appearance from the inner, the former frequently being rather like felstone in character. Thin slices having been made of a selection of these rocks in different parts, the microscopic structure of some of the most conspicuous and interesting will be described.

Seathwaite How (Fig. 18, Plate III.).—Quartz Diorite. Along the hill-side, just north of the railway between Cockermouth and Bassenthwaite Lake, occur several masses of Diorite of the same general character. Doubtless these are all more or less connected with one another beneath the surface, and the example now to be described is taken from one of the central and best developed masses.* It forms a very massive, well-jointed rock, fine-grained, and of a grey colour, the felspar being white, and the hornblende dark; scattered specks of iron pyrites also occur.

An idea of its microscopic structure may be gathered from Fig. 18, Plate III. The base consists of a crystalline mixture of felspar and hornblende, in the midst of which are small irregularly shaped patches of quartz, and many grains of pyrites.

The felspar is triclinic. Many long acicular crystals penetrate the mass in various directions, sometimes shooting out most clearly into the quartz spaces, as in the figure, where it would almost seem as if one long crystal, during its formation, had pushed in front of it small particles suspended in the then viscid quartz. These crystalline needles are only the $\frac{1}{10000}$th to the $\frac{1}{20000}$th of an inch in diameter, and sometimes have minute greenish granules of irregular form clustered about their ends and sides.

* Seathwaite How, and the whole of this hill-side, is just outside the limits of the 1-inch Map, but within the 6-inch Sheet 55, the greater part of which is included within 101 S.E.

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The quartz also contains many very minute liquid-cavities, from the $\frac{1}{5000}$th to the $\frac{1}{20000}$th of an inch in diameter, which contain actively moving vacuities. Glass-cavities also occur pretty frequently.

The hornblende is a good deal altered, but for the most part shows clear dichroism with the polarizer alone, and marked pleochrism when both prisms are used. None of the crystals are very definite in form.*

Little Knott (Fig. 19, Plate III.).—Diorite. The example about to be described is from one of several intrusive masses upon the east side of Bassenthwaite Lake, and about the northern margin of 101 S.E.

The rock is of a dark colour, highly crystalline, and appearing almost entirely hornblendic. A microscopic examination shows that it really is so, hornblende in various shades of brown and green, and having its usual striated appearance, occupying constantly the whole field of view (Fig. 19, Plate III.). Crystals and grains of pyrites, and perhaps of magnetite, are frequent.

There is very little felspar, and what little there is is much altered, though its triclinic character is shown in some parts. This rock forms a splendid object when viewed with polarized light, and when the polarizer is alone used the hornblende appears in most cases very markedly dichroic.

Hindscarth (Fig. 20, Plate III.).—Quartz Diorite. There are several patches of this rock, upon the summit and sides of Hindscarth. It is massive, and of a slightly greenish-grey colour.

The microscope shows at once its highly altered nature, represented in Fig. 20, Plate III. Its structure is very indefinite and confused, being made up of much green, interlacing, pseudomorphic matter, generally with a fibrous structure, and probably after hornblende. There are a few indications of triclinic felspar, and a great deal of quartz occupying the spaces between the other minerals. Many acicular crystals project into these quartz spaces (*see* Fig. 20), and these last also contain liquid-cavities with moving bubbles, the cavities being generally less than the $\frac{1}{10000}$th of an inch in diameter, and associated with numerous glass-cavities. There is a good deal of dichroism shown, partly perhaps by unaltered hornblende, and partly by chloritic or other pseudomorphic minerals. Epidote is apparent in small quantities and a few minute flakes of mica, while both pyrites and magnetite appear to be present.

Burtness Comb (Fig. 21, Plate III.).—Quartz Diorite. This rock occurs in the midst of altered Skiddaw Slate near its faulted junction with the Volcanic Series, and close to one end of the mass of Buttermere and Ennerdale syenitic granite. It is midway between the summit of High Stile and Buttermere. Hand specimens show small white crystals of felspar blended with a great deal of a dark green mineral.

* This rock is very similar, lithologically and microscopically, to a quartz-diorite described by Zirkel from Doiranaeach, Arran.

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The base is made up of orthoclase and plagioclase felspar (Fig. 21) mingled with green pseudomorphs after hornblende, and a good deal of quartz. The green pseudomorphic mineral is probably serpentine, since it shows under polarized light the structure and mottled, neutral-tint shades characteristic of that species. The quartz contains many liquid cavities with bubbles, and some glass cavities; also it encloses acicular crystals, which frequently seem to shoot out into it (see Fig. 21), as in the former examples. A few crystals and grains of magnetite or pyrites are present. In the figure, the appearance is attempted, as seen under polarized light. The colour-banded crystals are plagioclase, and two grey and brownish, dotted crystals, on the left side, are orthoclase. The irregular orange and neutral-tinted spaces, with dots and acicular crystals, are quartz, while the green probably represents some altered hornblende.

The preceding will serve as examples of the Dioritic class; there are many instances besides, but all cannot be examined in the same detail.

(c.) *Dolerites.*

All the cases of intrusive dolerite yet examined are so very highly altered that they would probably be included under the general term of Diabase.

Wythop Fells (Fig. 22, Plate III.)—In the neighbourhood of Wythop Hall are several small intrusive masses, and the following description applies to one a little south of the Hall, on the east side of Hagg Beck. Lithologically, it is a fine-grained, dark-green rock, though its outer parts are apt to appear very different. The microscopic examination shows a great deal of chlorite disseminated through the base, and replacing much of the felspar; the latter has, in parts, the banding characteristic of plagioclase. There are many spaces filled with quartz, which contains small cavities with bubbles, acicular crystals, and occasionally grains of magnetite. Some cavities filled with calcite also occur.

There are a few imperfect augite crystals, altered partly into a chloritic and partly into a granular substance; and acicular crystals, some of considerable length, are tolerably numerous.

Castle Head, Keswick (Fig. 8, Plate I.)—This is one of the most conspicuous of the smaller intrusive masses in the district. The rock is an intimate mixture of pale-coloured felspar with augite, and a soft, dark-green, pseudomorphic mineral, both chlorite and serpentine. There are numerous fine veins of some form of serpentine, probably picrolite, penetrating the rock in various directions, and showing a cross fibrous structure. Some cavities filled with quartz are lined with it also. Pinkish felsitic veins occur occasionally, while those of quartz and calcite are pretty numerous.

A microscopic study of this rock shows what an immense amount of alteration has taken place. Scarcely a fragment of felspar remains unaltered, and most of the augite is also replaced, the pseudomorphs being both chloritic and serpentinous. Many augite

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crystals however still remain partly unchanged, and some of these shew a well-marked twin structure in polarized light. Many long acicular crystals also occur in some parts.

Small flakes of brown mica are tolerably abundant, which are distinguished by their very marked dichroism from the reddish-brown patches of ferric oxide (see Fig. 8, Plate I.). Magnetite crystals are present, and grains of this mineral seem frequently to enclose small pieces of altered felspar, which are banded with black lines. Quartz and calcite fill occasional vesicles.

Swirral Edge, Helvellyn (Fig 7, Plate I.)—The rock now to be described occupies only a small area at the junction of Swirral Edge with Helvellyn, but intrusive masses of this class are not so plentiful in the Volcanic Series as one would at first suspect might be the case, and therefore it is taken as an example.

It consists of an intimate mixture of light-coloured felspar, with a softish, dark-green mineral, and some unaltered augite. A few scattered crystals of iron pyrites may also be detected by the unassisted eye.

The microscopic examination of this rock reveals several very interesting facts. Although it is now very hard and compact, its original state was evidently vesicular (Fig. 7, Plate I.), for in a thin slice there are seen numerous spaces of irregular form filled with a green mineral, but edged with many small oval and clear granules. In polarized light, the central parts of these vesicles are black under crossed prisms, but the margins transmit light, showing that the granules are composed of some doubly refracting mineral. Although they are mostly collected along the edges, a few occur scattered in the heart of the vesicles.

The general base is made up of small felspar crystals, both plagioclase and orthoclase; and augite seems to have been pretty plentiful, though many of the small crystals of this mineral are converted into the same green substance which fills the cavities. Magnetite is tolerably abundant in parts.

Longstrath, Borrowdale.—Across the upper part of the Longstrath valley there run a number of branching dykes, some few of which extend for a long distance to the north-east. The rock composing them contains distinct felspar crystals embedded in a felspathic base, with which is mingled a good deal of a soft, dark-green, pseudomorphic mineral. Occasionally red veins traverse the mass.

Viewed under the microscope, the rock is found to be highly altered, there being a great deal of chloritic matter disseminated through the base. In the slice examined, there is no unaltered felspar, but there are several good crystals, and groups of crystals, of augite, together with magnetite and pyrites. The red veins are felsitic.

Some intrusive rocks immediately connected with the Plumbago Mine (Fig. 24, Plate III.) are described under that head.

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CHAPTER VII.

GENERAL POSITION AND LIE OF THE ROCKS.*

If the reader will look at the One-inch Map 101 S.E., or the small map appended, Plate IV., he will see that a somewhat zig-zagging diagonal, drawn from N.E. to S.W., parts the Skiddaw Slates on the N.W. from the Volcanic Series on the S.E. The direction of this diagonal represents the general strike of the two formations, the dip being mainly to the S.E., but subject, especially among the Skiddaw Slates, to frequent reversal, due to folding and contortion of the beds.

(a.) *Position of Granites, Quartz Felsites, &c.*

The Skiddaw Granite occurs partly between and partly behind (*i.e.* north of) the mountain masses of Skiddaw (1) and Blencathra (2), a small area of it being exposed in the course of Sinen gill, and larger masses in the valley and bed of the river Caldew, draining to the north.

Its metamorphic effects are seen among the Skiddaw Slates for considerable distances, from Skiddaw on the west to north of Scales Tarn and Bannerdale on the east.

The St. John's Quartz Felsite occurs at the northern end of the Vale of St. John in two large, rudely-oval and separated masses, each about one mile long from N. to S., the Skiddaw Slate being seen at one or two spots between them.†

The Buttermere and Ennerdale Syenitic Granite occupies a tract of country continuously, some seven miles N. to S. and three miles E. to W., its northern edge ranging from the head of Mosedale (W. of Crummock) by Scale Force to the foot of Buttermere. A considerable area of altered Skiddaw Slate runs into this mass from the head of Mosedale and forms Starling Dodd (24), which is thus almost surrounded by syenitic granite.

It will be needless to describe the positions of the smaller intrusive masses of Diorite, Dolerite, &c., they will be seen on the One-inch Map at a glance. The largest such intrusive mass is that of the Dolerite (or Diabase) forming Castle Head, near Keswick.‡ Although there is an interval without any section, it seems tolerably certain that the rock of Cockshot Wood and the dyke forming Friar's Crag are continuous with the Castle

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* By "position" is meant the place in which such and such rocks will be found; and by their "lie" is meant the form and manner of their occurrence, their angle of dip, &c.

† Dr. Nicholson, in 1869 (App. 53), supposed this rock to be continuous across the valley.

‡ Not inserted in the small Sketch-map, since no train of boulders has been traced from it.

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Head rock, and these in all probability with that of Rosetrees and Silver Hill upon the west side of the lake.*

(b.) *Position and Lie of the Skiddaw Slates.*

Since, unfortunately, this series does not contain many well-marked beds of sufficiently constant thickness to allow of their being traced with certainty across the country, the best method will be to point out by a series of horizontal sections, the character of the beds in different parts, and their lie.

The lines along which the sections in Plate XI. are drawn, are marked upon the Sketch Map, Plate IV. The sections are upon the scale of one inch to the mile, both vertical and horizontal, and thus represent not only the geological structure but the physical conformation of the district. Many of the small faults and veins are omitted, for the sake of clearness.

No. 1 shows the lie of the Skiddaw Slates from the northern end of Fellbarrow to Scale Beck, where they strike against the Buttermere syenitic granite. For the most part the beds are hard and flaggy (represented by the dotted parts in the section), but in the lower ground between Fellbarrow and Darling Fell, and about Park and Scale Becks, they are more argillaceous and shaly (represented by fine parallel lines). It will thus be seen that in all probability the strata forming the long and low synclinal of Mellbreak are partly the equivalents of the uppermost beds of Darling Fell, the valley being occupied by an anticlinal. The fine *cross* lines in Mellbreak represent cleavage.

No. 2, beginning at the northern end of Swinside (S.E. of High Lorton), crosses the summits of Dodd, Whiteside, and Grasmoor, and running along the hill-side nearly parallel to Buttermere, leaves the Skiddaw Slate abutting against the Volcanic Series of Fleetwith Pike and Honister.† The intrusive trap of Dodd separates gently rolling, flaggy beds, on the north, from the highly inclined similar strata of Whiteside, along the southern slopes of which mountain these gritty beds dip under and are partly faulted against a considerable thickness of black, splintery, and flaky slate. From beneath this black slate occupying the valley, arise the somewhat massive, sandy beds of Grasmoor, the equivalents of those of Whiteside, the valley between the two mountains thus representing a broken synclinal, the axis of which is to the north of the river bed, while Grasmoor End forms a very exceptional instance of a mountain summit occupied by beds in an anticlinal

* I can find no evidence for the identification of the Silver Hill rock with the Borrowdale Series, and for its being thrown down by a great east and west fault, as supposed by Dr. Nicholson, and I feel sure that in this, as in several other cases in which I may be obliged to differ from him, he would have come to other conclusions had he spent the time upon the ground that I have happily done. I, in common with all, must feel a debt of gratitude for the able work done in this district by Profs. Sedgwick, Harkness, Nicholson, and others, and although direct reference cannot always be made to their papers in the text, a full list of these is supplied at the end of the Memoir.

† The throw of this fault may not be so great as represented in the section, but in the absence of definite evidence it has been thought best to give it as shown in Plate XI.

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position. Southward, these strata are a good deal contorted, and dip under a series of a more shaly nature, which in their turn pass beneath the gritty beds of the hill-side between Hassness and Gatesgarth.

No. 3 shows the lie of the slates from the district west of Bassenthwaite Lake, across some of the Wythop Fells and Whinlatter, the eastern ridges of Grisedale Pike, the summits of Outerside and Causey Pike, to Maiden Moor, on the eastern side of the Vale of Newlands.

The sandy and gritty beds of Setmurthy Common and Watch Hill (a mile beyond the northern edge of 101 S.E.) are underlaid by others more shaly, probably occupying much of the low, alluvial, and drift-covered ground in the Embleton valley. Dipping beneath these come the flaggy and rather sharply-folded strata of Ling Fell, forming farther south the low synclinal on the west end of Broom Fell, and then rolling over beneath Whinlatter at a somewhat high angle, which is continued across the Pass until the dip once more changes to form an undulating low synclinal upon the eastern spurs of Grisedale Pike. On the northern side of Coledale there are symptoms of a considerable disturbance, and in all probability two faults, continuous with those south of Whiteside, throw contorted beds of a somewhat higher horizon against those just described. Thus Coledale, again, represents a broken anticlinal formed of somewhat shaly beds; while Outerside and Causey Pike, to the south, are capped by some of the same strata as occur north-west of Grisedale Pike, thrown into gentle synclinal curves. Crossing the wide Newlands Vale the section is very obscure, but upon the east side a series of black slates and flaggy beds—which probably for the most part overlie those of Causey—are much contorted, cleaved, and traversed by veins, many of which are, most likely, faults also; these beds are then faulted against the Volcanic Series of Blea Crag.*

No 4. traverses the Skiddaw Slates from the east side of Bassenthwaite Lake, over Dodd, along the low southern slopes of Skiddaw, across Latrigg and the valley of the Greta, to Castlerigg, a little south of the Ambleside road.

Flaggy and shaly beds alternate upon Dodd, forming a well-marked synclinal, somewhat broken by dykes of intrusive micaceous trap, which themselves seem often to be the axes of small subsidiary synclinals. A great deal of the south-eastern part of this section, through the slates, is rather doubtful, the true dip of the rocks being much concealed.

No. 5 shows the two granitic masses of the Caldew and Sinen Gill, with the altered, highly cleaved, and foliated slates around; the line of section running nearly north and south on the east side of the Glenderaterra valley. Along this line the slates terminate on the south against the western mass of the St. John's quartz felsite, although small inliers occur among the felsite a mile farther south (see p. 8).

No. 6 shows the lie of the Skiddaw Slates, so far as can be

* See note † on previous page.

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gleaned from scattered sections, between the volcanic rocks of Eycott Hill on the north and those of the northern end of the Helvellyn range on the south. The beds are for the most part black and shaly and probably represent some of the topmost of the series.

No. 9 traverses some of these same beds between Greenahcrag and Mell Fell, and again south-west of Mell Fell. Their precise lie, however, is very doubtful.

In No. 10, between Matterdale and Ullswater, the Skiddaw Slates occur at either end, but it is impossible to say of what magnitude the bounding faults are, and whether the slates should be represented as partly underlying some of the volcanic rocks in the section, which seems most likely to be the case.

In Plate VII., the lie of the slate from Skiddaw to Blencathra (Saddleback) is shown, the low dip to the north-west of a great part of the rather flaggy beds of black slate being a distinctive feature in the latter mountain, and probably combining with the high cleaavge planes, in an opposite direction, to form its grandly ravined front with parting edges, and its smoothly sloping back. The four dotted cross lines in this section show the outer limits respectively of the Chiastolite Slate and Spotted Schist, the fine parallel cross lines representing the cleavage. Some of the harder and more gritty beds about Skiddaw may be seen in the course of Tongue Beck, between Little Man and Broad End.

Viewed as a whole it would seem that there are in this district probably two sets of gritty and flaggy beds in the Skiddaw Slate series, the lower being by far the most important, and mainly forming the mountains along the N.E. and S.W. axis of the Skiddaw Slate area, while the more shaly beds, with sometimes the upper series of sandy strata, roll away to the south-east and north-west on either side. Thus it happens that no estimate can be made of the true thickness of the series, since the underlying formation, whatever that may be, is never exposed. Moreover, in passing from one part of the district to another, flaggy and sandy beds become argillaceous, and the reverse, so that few definite horizons being determinable, it becomes hard to make even a fair approximate estimate of the thickness of the series exposed. Between (the Lorton) Dodd and Whiteside (Sect. 2) there is a pretty constant dip of flaggy bed , which represents a thickness of about 1,400 feet; and if one could rely upon there being no undetected faults between Hobcarton End and the valley parting Whinlatter from Broom Fell (Sect. 3), a thickness of some 7,800 ft. of these more or less flaggy beds would here be represented. Similarly, the section through Blencathra gives us a thickness for that part of the series of over 5,000 ft. It seems likely that the flaggy beds thicken much westwards,* and in the next one-inch map (101 S.W.), the upper series is represented by a grit, seen on Lank Rigg and Latterbarrow;† while according to

* Prof. Harkness came to this conclusion also in 1858 (App. 37).

† The grit of Great Scafell, Great Cockup, and Watch Hill, in 101 N.E., is probably the representative of that of Latterbarrow and the gritty beds of Gatesgarth.

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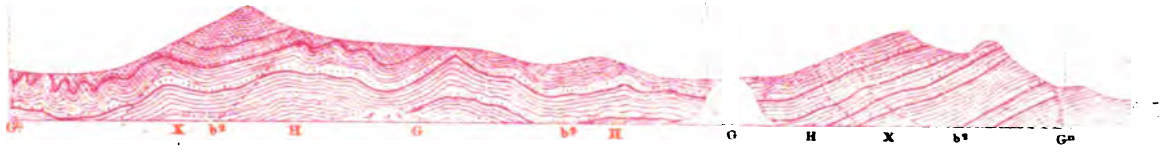
Section through Skiddaw and Blencathra.



b^{3} Diorite X Chiastolite Slate H=Spotted Schist G=Granite b^{2} Skiddaw Slate NOTE-The boundary lines of the granite should probably be less steeply inclined than in the figure.

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Profs. Harkness and Nicholson* the gritty character is strongly developed in some parts of the series in the Isle of Man. Taking then the thickness of the flaggy series of Whiteside to represent that of a part of the lower division, I should be rather inclined to think that Prof. Harkness's estimate of about 7,000 ft. for the *complete* series is more likely to be below the mark than above it, and that 10,000 or even 12,000 ft. might more truly represent the thickness as exhibited in this area.

(c.) *Position and Lie of the Volcanic Series.*

The rocks forming the Volcanic Series of Borrowdale occur in the map 101 S.E., over its south-eastern part. The small area occupied by them in Eycott Hill is the eastern end of a skirting of these rocks upon the other side of the great Skiddaw Slate anticlinal, and they run round to the west beneath the Carboniferous Limestone as far as Cockermouth.

That part of the series seen on Eycott Hill consists of a succession of beds of lava with comparatively little interstratified ash, the beds dipping to the north-east (see Sect. 6), and having a total thickness of nearly 3,000 ft. The junction between this series and that of the Skiddaw Slate seems here, as elsewhere in this one-inch map, to be a faulted one; beds on different horizons abutting against the area occupied by the Slate. It would seem probable, however, that this fine set of contemporaneous traps very nearly represents the base of the Volcanic Series, since there occurs a thin bed of Skiddaw Slate amongst them. One section of this bed is at the lower end of a ravine made by a small stream a little south of the summit of Eycott Hill. Beneath the fine porphyritic dolerite, previously described, comes a blue basalt, a few feet in thickness, disappearing northwards; then a band of altered Skiddaw Slate, 6 to 10 ft. thick, with basalt beneath; while a little below, crumpled slate is seen in the stream-bed on the west side of the fault. The bearing of this interstratification will be considered in Chapter XII. The lowermost beds in this Eycott Hill group are, in descending order, as follows:—

	Feet.
Porphyritic dolerite - -	125
Skiddaw Slate - - -	6 to 10
Basalt, compact and vesicular -	400
Purple ash, thickness unknown.	

An interval of nearly two miles occurs between the southern faulted boundary of this series and the next exposure of volcanic rocks upon the south-west side of Mell Fell, the intervening area being occupied by Skiddaw Slates and red conglomerate.

The lie of the beds composing the main mass of the Volcanic Series will be most easily described by referring first to a line of section running through the best developed and most typical part —about the centre of the area—and, afterwards, following the course of the beds to the east and to the west.

Section 4 (Plate XI.) passes through the series of lavas and ashes described in Chap. IV., from north to south, and shows

* *Quart. Journ. Geol. Soc.*, vol. xxii. p. 490.

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that the various beds form a low and somewhat faulted synclinal curve, the central point of which is the summit of Bleaberry Fell. Farther south, the beds of underlying ash crop up and form an anticlinal, the axis of which seems to be an east and west dyke, crossing from Watendlath to Armboth. Upon the south side of this anticlinal the traps of the Bleaberry Fell series again come in, though much diminished in thickness, succeeded by alternations of coarse and fine ashes with an intercalated bed of lava, and cut through by occasional dykes and faults.

The line of section next to the east, No. 5, passes through pretty much the same series. First, on the north, is the long faulted synclinal of High Rigg, the lava-beds roughly corresponding to those of the Bleaberry Fell series. It is admirably seen from the lower end of the Vale of St. John, the dipping beds and the lines along which they are broken by faults being marked out on the mountain side as in a geological model. The regular structure of the succeeding anticlinal to the south, is rather broken by the St. John's and Thirlmere Valley fault, but upon the east side the lavas again come in dipping south-east and apparently dying away upon the Helvellyn range north-eastwards. A considerable thickness of ash overlies these, with an included thick and massive lava-bed, the whole being much traversed by dykes and veins, west of Helvellyn summit. Near the Helvellyn Lead Mines, an east and west fault appears to throw down strata of somewhat a different character, with a general dip rather to the east than south-east. Upon the mountain summit the ash is mostly rough and cleaved, passing down, on Whelp Side, into some very finely-bedded, lying upon lava of no great thickness, with a little coarse ash below, and then much fine, felstone-like, altered ash, in which bedding may be detected in places. This highly altered ash is represented in sections by the parts left almost undotted, and in Sect. 5 a possible mass of granite is inserted which is not exposed anywhere at the surface, but the existence of which is inferred to explain the metamorphic character of the beds, similar to that found to prevail on approaching the great mass of Eskdale granite.

That part of the volcanic series shown in Sect. 6 scarcely needs any comment; there is very little lava except in the Eycott Hill area already spoken of, and the ashes, though much altered in places, as about Great Dodd and Glencoindale Head, consist of the usual alternations of coarse and fine material with occasional breccias, while along the southern part of the section they are much cleaved (see fine cross lines). Section 10 cuts the thin lava-beds of Thornythwaite, apparently abutting against the Skiddaw Slate along a faulted line west of Matterdale End, and being underlaid and overlaid by ashes, which in some places are highly felspathic and cleaved, and in others a good deal altered.

Returning now to the west of the most typical section crossing Bleaberry and Armboth Fells, the lie of the beds may be seen by reference to Sect. 8, where what represents the Bleaberry Fell series is seen in force upon Watendlath Fell, around Dock Tarn;

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the Watendlath and Armboth anticlinal dying out westwards between Watendlath and Brund Fells. Thus, much of the ash of Grange and Brund Fells represents that of Ashness Fell upon the eastern side of the Watendlath Valley. Above the Dock Tarn lavas there is a considerable thickness of ash which has undergone much alteration, succeeded again by less-altered coarse and fine beds, some of the last being pretty well cleaved. Upon or a little south of Ullscarf, the strata form a low synclinal.

Section 7 shows the sequence from the base of the lava series upwards. The highly altered ashes on Rosthwaite Fell, overlying the lava-beds, are here much thicker than in the last section, or rather it should be said that the alteration has here affected a much greater thickness of beds than farther to the east. The southern part of this section-line crosses the intrusive masses and dykes of Longstrath, and then shows altered, fine and coarse ash, dipping southwards at from 8° to 10°.

Along the course of Section 3, between Blea Crag and High Scawdel, a number of thin beds of lava are met with, overlying strata of altered ash and breccia, and which probably are on about the same horizon as the lavas of the Falcon Crag Series, though they are very inconstant. Next to the south comes a faulted piece of country with ash, evidently much metamorphosed, containing one or two thin lava-beds. Above these, and just north of the Plumbago Mine, occur other similar beds, the meagre westerly representatives of the thick lavas of Rosthwaite and Watendlath Fells, and which appear to die away altogether further west. At this point the line of section shows the intrusive masses in connection with which the Plumbago Mine occurs (see Chapter X.), and south of them, there are seen in succession, ash and breccia; fine, bedded, and altered ash; a great thickness of highly altered felstone-like ash (on and about Base Brown); and lastly, coarse ash, less and less altered, with intercalated finer beds still much metamorphosed. Along the line between the Plumbago Mines and Sprinkling Crags there are several spots where the altered ash has quite a columnar and, in almost every respect, trap-like appearance; nevertheless the most insensible gradations can be traced from the purely trap-like to the purely fragmental rock, beds of fine and but little stratified material being the most changed.

Some of these same beds are seen in Section 2, in which the numerous thin lava and cleaved ash-beds of Honister, are succeeded by the coarser and altered ash of Grey Knotts, overlaid by the fine, bedded, altered ash of the south-east side of Sourmilk Comb, and the still more metamorphosed fine ash of Base Brown, dipping south-east at a high angle.

The series of thin lava-beds which may be traced from immediately west of Castle Crag, Borrowdale, across Dale Head and Honister, to Scarf Gap, where one is of very considerable thickness, cannot be definitely followed to the south-west, though several such beds of inconstant thickness do occur. In Section 1, the syenitic granite, capped by altered ash and Skiddaw Slate on the summit of Red Pike, is succeeded on the Pillar Mountain—

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apparently in a conformable manner—by a great series of ashes and breccias with occasional lavas, all becoming highly altered as the granite of Wastdale Head is approached, which is seen on the southern slopes of Kirk Fell and in the bed of Lingmell Beck.

From the preceding description it will appear that the difficulty of tracing beds of contemporaneous trap over a highly mountainous country is greatly increased by their very inconstant thickness, rendering the task of identification of beds very hazardous indeed in many cases. Still, as I think there can be little doubt that the series of lava-beds in Rosthwaite and Watendlath Fells is the same as that of Bleaberry Fell and High Seat, this gives us a horizon so long as the lavas do not wholly die away. The identification of the Honister Series with that of Falcon Crag, while somewhat more doubtful, is still probable, the ash, feebly represented between the lavas of Bleaberry Fell and Falcon Crag, having much thickened to the south and south-west.

The thickness of the Falcon Crag and Bleaberry Fell Series, as represented in the section, Plate V., p. 13, is about 2,800 feet. Whether or not the Eycott Hill beds are the equivalents of those of Falcon Crag and Bleaberry Fell it is not easy to determine, for although the thicknesses of the two series seem to agree very fairly, yet the nature of these volcanic deposits forbids any strict correlation of strata far distant from one another.

I do not think 12,000 feet, or perhaps 15,000 feet, is too high a *maximum* for this Volcanic Series, very nearly the whole thickness being represented in this quarter-sheet.* The highest beds of the Volcanic Series are probably those forming the summits of Allen Crags, Great End, and Esk Pike,† consisting of highly altered, flinty, and bedded ash, overlying the unbedded coarse ash which occurs immediately south of the top of Glaramara, and forms the line of steep crags, on the Scafell Pikes range, between Broad Crag and Long Pike (Great End).

Thus, the following is the general sequence of the Volcanic and Skiddaw Slate Series as a whole, in descending order :—

Volcanic Series, about 12,000 ft.

9. Bedded, mostly fine, flinty‡ ash, of Great End, Esk Pike, and Allen Crags.
8. Unbedded, coarse ash and breccia, of Broad Crag and Long Pike.
7. Bedded and rough ash of Scafell Pikes, Glaramara, and Ullscarf.
6. Partially bedded, fine, flinty ash, of Base Brown and Rosthwaite Fell.
5. Well bedded ash of Seathwaite.
4. Contemporaneous traps of Watendlath Fell, High Seat, and Bleaberry Fell.
3. Breccia and bedded ash, of Brund Fell, and Watendlath.
2. Contemporaneous traps of Honister, Dale Head, Gate Crag, and Falcon Crag.
1. Purple breccia, ash, and some contemporaneous trap.

* Prof. Harkness and Nicholson give the average thickness as not more than 5,000 feet (App. 59), but this is certainly an under estimate, as a glance at the sections in Plate XI. will show.

† All of which are in 98 N.W., immediately to the south of 101 S.E. Esk Pike (2,902 ft.) is the hitherto nameless mountain lying between Esk Hause and Ore Gap.

‡ The word "flinty" is here used as an adjective term, to denote a close, hard, and compact *texture* like that of a flint.

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Transition Beds.	Interbedded volcanic strata, and Skiddaw Slate.
Skiddaw Slate, 10,000 to 12,000 ft.	5. Black slates of Skiddaw.
	4. Gritty beds of Gatesgarth (Buttermere), Latterbarrow (101 S.W.), Tongue Beck (Skiddaw), Watch Hill, and Great Cockup (101 N.E.).
	3. Dark slates.
	2. Sandstone series of Grasmoor and Whiteside.
	1. Dark slates of Kirk Stile, between Loweswater and Crummock.

The subject of the correlation of these Skiddaw Slate Divisions with some of the Lower Silurians of Wales is one upon which I hope to be able to throw some light by continued investigation. Judging mainly from the sequence of lithological divisions, as compared with those of North Wales, I should be inclined to regard No. 5 as Arenig (U. Arenig of Hicks), No. 4 as the Carnarvonshire Grit and Stiper Stones (M. Arenig of Hicks), No. 3 as Tremadoc, and Nos. 2 and 1 as Lingula Flags. If subsequent research prove this to be correct, the period represented in Wales by the Aran and Arenig volcanic beds, the Llandeilo Slates, and the Snowdon volcanic series, is represented in Cumberland by one continuous volcanic formation—in the one case (Wales) by mostly sub-marine volcanic and slaty strata, in the other (Cumberland) by mostly sub-aerial volcanic deposits. In Wales, the Bala Limestone forms the top of the series, and in Cumberland the Coniston Limestone.

(d.) *Position and Lie of the Basement Conglomerate and Carboniferous Limestone.*

The Conglomerate of Mell Fell (Section 9) is but a portion of a larger area of the same, stretching eastwards in the next map to Pooley Bridge at the foot of Ullswater, and probably continuous northwards with a narrow strip beneath the limestone, south-east of Eycott Hill, where its character is that of false-bedded, fine conglomerate, containing thin bands of sandstone with plant remains, which may be seen in a little stream-course west of Whitbarrow.

The *apparent* general dip of the conglomerate of Mell Fell and Little Mell Fell (farther east) is S.E. and E.S.E. at an angle of from 15° to 20°. That west of Whitbarrow apparently dips a little north of east at a much less angle, and thins away altogether about Berrier. It is very hazardous, however, to judge of the dip of false-bedded, conglomeratic beds, from small exposures at considerable intervals.

The Carboniferous Limestone Series only enters into 101 S.E. at quite the north-east corner; but within the limits of the six-inch map 57, which extends about a mile and a quarter beyond the boundaries of the one-inch, there are no less than eight or nine beds of limestone alternating with as many of a softish, red sandstone, associated with which are a few shale bands and a thin coal or two. These beds dip to the N.N.E. at angles of from 8° to 12°, and in Greystoke Park, the limestone series surrounds an interesting faulted inlier of the volcanic rocks, consisting almost wholly of contemporaneous trap similar to that of Eycott Hill.

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CHAPTER VIII.

FAULTS.

What will now be said of the faults affecting the rocks of this area will chiefly relate to that part of it over which the Volcanic Series occurs, since among the Skiddaw Slates it is almost impossible to fix on many such lines, owing to the want of traceable beds, and the evidence of faulting derived from the shifting of such beds. There is every reason, indeed, to believe, that the Skiddaw Slate is traversed by very many faults, which increase the difficulty of the correlation of the different parts of the series immensely, and all the more so because they are generally undiscoverable. In many, if not in all cases, the mineral veins are likewise faults, though among the Skiddaw Slates it is often difficult to prove them such. The faults already mentioned in Whiteside and Coledale (see Sects. 2 and 3), and some doubtful lines of faulting north and east of Loweswater are the most important in the Skiddaw Slate area, apart from mineral veins, which will be dealt with in a chapter by themselves. There is, I think, evidence of a line of fault passing down the Crummock and Lorton valley, in the want of correspondence of the various sub-divisions on either side, the dark slates of Kirk Stile (between Loweswater and Crummock) being, I believe, on a lower horizon than the sandstone beds of Grasmoor and Whiteside, which are probably the lowest strata occurring on the east side of the valley. Any direct evidence of the *actual line* of this fault, is, however, wanting.

The most important case of faulting in the district is that of the great compound boundary fault between the Skiddaw Slates and the Volcanic Series. It may and it certainly does seem strange that for so long a distance the two formations should show no natural junction, whether conformable or otherwise. And yet I think the evidence is conclusive that such is the case. It will be seen on referring to the one-inch map that beds on very different horizons are constantly brought against the Skiddaw Slate, and if the line of junction be carefully followed throughout its length, over mountain-top and across valley-bed, there will be frequently seen evidence of slickensides, and of the older and newer formations being brought face to face as along lines of fault. The boundary, in fact, appears to be formed by the constant meeting of faults having a more or less north and south direction, with others having a more or less east and west course, the two frequently meeting at right angles with each other and letting down the rocks between them.* It is

* In 1866 (App. 46), Profs. Harkness and Nicholson state that there is not "sufficient evidence to show that any unconformability exists between the Skiddaw "Slates and the succeeding green rocks," p. 481. In 1868, Dr. Nicholson began to doubt this conclusion (App. 48). In 1869, Mr. Dakyns described a supposed unconformity (App. 51, 52); and Dr. Nicholson also concluded that the two series were unconformable (App. 55). The latter has certainly taken beds on very different

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quite unnecessary to describe in detail the course of each division of this long zigzag line of fault. The most marked east and west portion is that from Matterdale End to a little south-east of Keswick; in the course of Matterdale Beck, the black Skiddaw Slate and the felspathic ashes of the Volcanic Series are much smashed together, in some places producing an appearance of conformity. The most marked north and south portion of this long line of fault runs from just south-east of Castle Head, Keswick, along the eastern shores of Derwentwater—where in one place the Skiddaw Slate may be seen thrown against the ash—and up into Troutdale, east of Grange. Where the faulted boundary crosses lofty and steep mountains its hade necessarily causes it to project northwards in angles upon the mountain-tops, and southwards in angles or curves in the valley bottoms, just as is the case with strata having a similar dip and strike, and as may be observed in many of the beds of contemporaneous trap near the faulted junction.

Since a defined base to the Volcanic Series is not exposed anywhere in the neighbourhood, it is impossible to form a correct idea of the magnitude of the throw along the various parts of this line of fault; hence, in the sections, I have preferred (except in Nos. 3, 6, and 9) to put in the volcanic rocks quite down to the datum or sea-level line, although, doubtless, this may very greatly exaggerate the throw of the faults in most cases.

Besides this great boundary fault, there are many others traversing the Volcanic Series, and traced out by the effects they have produced in shifting the various beds of lava and ash. Most of these have a N. and S. or N.N.W. and S.S.E. direction. Conspicuous amongst them is the fault which, coming from the south, through the pass of Dunmail Raise, skirts the base of the Helvellyn range, roughly parallel to and east of Thirlmere, and passing throughout the length of St. John's Vale, may possibly range northwards up the Glenderaterra Valley.* The evidence for this fault is derived from the general want of correspondence of the beds on either side of the valley, and its slickensides may be seen at one point in its course, namely, the first sharp stream-bend south of the Wythburn turnpike.

Other faults with a general north and south direction strike along the course of the Shoulthwaite and the Watendlath valleys, and many similar but less lengthy ones, may be seen by a glance on the map.

The east and west faults seem by no means so numerous or well-marked, but this may partly arise from their not crossing the *strike* of the beds so much as the north and south series, and therefore

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horizons to be one and the same contemporaneous felspathic trap, which he supposes to occur at the base of the Series, and of which the (undoubtedly intrusive) mass of Castle Head, Keswick, is given as a sample (App. 60). As the various beds were not traced in detail, such an error was, doubtless, unavoidable. The true relation between the two series of rocks—that of conformity—is noticed in Chap. XII. of this Memoir.

* Noticed by Prof. Harkness (App. 46).

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not being so easily detected by their effects. They often form mineral veins, and are frequently discovered mainly on that account.

Of the two series, those faults having a more or less east and west course appear, *generally*, to be the older (see also Chap. XII.), and are often shifted by the north and south faults.*

* Messrs. Harkness and Nicholson state (App. 46): "There are in the lake-"country two distinct systems of faults, but they are not confined to it; they occur in "the North of England wherever the older Palæozoic rocks present themselves, and "they belong to different periods. The system which has a north-east and south-"west direction, is older than the other . . . . they in no way affect the Upper "Old Red. The second system of faults, which has nearly a north and south course, "is newer than the Carboniferous age, and was probably produced even after the "Permian epoch."

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CHAPTER IX.

MINERAL VEINS.

The following is a list of the various kinds of mineral veins and deposits which have been or are being worked in the district comprised in 101 S.E.:—

a. { Lead. / Zinc.
b. Copper.
c. Iron.
d. { Barytes. / Manganese.
e. Cobalt, &c.
f. Plumbago.

As a *general* rule the Lead and Iron Lodes run either N. and S., or N.N.W. and S.S.E.; the Copper Lodes, E. and W. These form the majority of the Mineral Veins. A few words will now be said about those of each class of mineral.

The direction of the various lodes as given in these pages is the *true* bearing, but it must be borne in mind that the miners themselves use magnetic bearings, so that a lode coursing, *magnetically* N. and S. has, *geographically*, a course of about 21° W. of N.

(a.) *Lead.*

Thornthwaite Lodes (Keswick United Silver Lead Mines). There are two principal lodes worked, both running N.N.W. and S.S.E. The *Thornthwaite Lode* hades east, is sometimes 20 ft. wide and very gossany at the top. With the galena there is a great deal of blende, which however often keeps very much in strings by itself. Carbonate of lead occurs in great abundance but crumbles very readily on exposure.

The *Rachel Wood Lode* hades to the west, but has been proved for only short distances at present.

The *Beckstone Vein*, along which there are some old bell-pits, has not been worked for about 40 years. There are several *contra* veins mostly running N.E. and S.W., and small dykes of intrusive trap (Diorite?) which are said to enrich the lodes.

Crossing Comb Beck are a couple of veins called the *Ladstock Lodes*, which have been opened out very slightly and would appear to run together a little west of Ladstock Wood.

Glenderaterra Lodes.—The oldest workings—some fifty years old—are in the course of the Glenderaterra river, a little south of Roughten Gill. The lode runs a little east of north, and south of west, and was opened out again in 1872, but has since been abandoned. It has been *proved* but very little south of the new shaft, and on approaching Roughten Gill seems to split up into strings.

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A vein with the same general direction has been worked lower down the valley, at the Blencathra Lead Mine. It lies 12 fathoms east of the shaft and was worked some eight or nine years ago a short distance to the north, where it becomes "broken"; southwards it has not been *proved*. Short levels have been driven lower down the river, but no veins were cut. An E.N.E. and W.S.W. vein joins the Blencathra Lode just south of the river bend. In the Lonscale Crags, on the west side of the valley, there are several veiny strings which may join the lodes at certain points and help to render them productive.

Saddleback (or Blencathra) Lodes. — The *Woodend Lode* striking N.W. and S.E. was worked about 18 years ago and is now being opened out again. A good deal of blende occurs with the galena, and the vein is rather "sulphury." The water from the low level of this old mine is very strongly coloured with iron, and interesting deposits of brown and red iron ore have been formed within the levels during the past 13 years, sometimes in the form of stalactites and stalagmites, and in one instance, in that of a vertical sheet, a couple of inches thick, extending two feet in width across the level. Specimens of this deposit, as also specimens of samples of ore from the various mines of the district, are preserved in the Keswick Museum. Another lode having the same course is being opened out higher up Gate Gill, and seems to give good promise; the galena is much of it very well crystallized. Both the Woodend and Gate Gill Lodes are found to change their hade a good deal, and seem to yield best where the inclination is least. The vein in Blease Gill was very little worked.

Loweswater Lodes.—The N.W. and S.E. lode crossing the valley near Scalehill Bridge was worked more than 30 years ago, and a good deal of lead extracted. Another, with a similar course, crosses Park Beck near Kirk Stile, and was worked a little some nine or ten years since; a third, running parallel to the two previous, between Whiteoak and Highnook Becks, was also worked about the same time, but although a great deal of ore was extracted the workings were not carried on to any extent. Another small working for lead was made some 40 years ago, on the west side of Mosedale Beck, beneath Hen Comb.

Newlands Vale Lodes.—Running N.N.E. and S.S.W. through Scope End, are two lead veins both hading east and apparently shifting the Goldscope Copper Lode, presently to be mentioned.

The *Scope End Lode* (the most eastern of the two) was found very rich near its junction with the Goldscope east and west copper lode, but did not yield very well farther south. *Sealby's Lode*, running parallel with the last, some 20 to 40 fathoms west of it, was never fairly opened out.

The *Castlenook Lode*, towards the head of Newlands Beck, has been worked at various times though not to any great extent, and some pretty good ore extracted. It hades east and courses nearly N. and S. Another, having the same hade and course, has been lately opened into upon the east side of the Beck, west of and

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beneath Maiden Moor. It may be called *Francis Lode* from its discoverer, and contains some beautiful looking ore in a crumbling quartzose vein-stuff.

The *Yewthwaite Lode* runs about N.N.W. and S.S.E., hading to the N.E. at an angle of 75°. The vein stuff is quartzose and crumbling. Its average width, where ore-bearing, is 2 ft., but it is sometimes nipped to a mere barren string. Some fine specimens of lead carbonate have been found in the upper part of the workings, and southwards there is a good deal of blende, where also there are many slides crossing the vein filled with a dark clayey material, the lode being inferior.

The *Barrow Lode*, believed to be a continuation of the Yewthwaite, crosses the mountain called Barrow, a little south of Braithwaite. It seems here to be in two parts, the supplementary one, being called the *Sandy Vein* and about 15 to 20 fathoms from the other. Much of the veinstone is very like that of the Thornthwaite Lode, gossany, and having some stony bands meeting and crossing it, yielding good bunches of lead-ore. It is, indeed, generally thought that the Thornthwaite, Barrow, and Yewthwaite Lodes are all one and the same vein.

The *Stonycroft Lode*, which probably joins the Yewthwaite and Barrow a little south of Stair, runs N.W. and S.E., hades to the north, and was worked about 16 years ago, though there was not very much ore got. There are a good many old grubbings on the backs of veins round the flanks of Rowling End, but very little or nothing is known about them.

The Brandelhow Lode has a general N.N.W. and S.S.E. course, hading to the east. The main workings have been at the south end of the Brandelhow Park Wood. The lowest were at the 50 fathom level; none were carried for a greater distance than 1,500 feet from the lake, measured along the lode. The vein divides, sending off a branch to the west, at 820 feet from the lake, north-westwards. It courses southwards along the side of Manesty Coppice and Low Park, and was worked some 15 years ago east of Manesty. Northwards the lode crosses Skelgill Bank, where there are old open-works in it, and it is believed to range across the valley to a little east of Thornthwaite, between which place and the railway it is supposed to run parallel with the Thornthwaite Lode. The following analysis of a Saline Spring occurring in the Brandelhow Mine I copy from a paper by Mr. Thomas Ransome.*

"The entrance to the mine is several feet above the lake, and a level of 200 yards in length is driven into the hill. At the extremity is the spring from which this water is taken; it rises through a small hole in the slate rock.

"The water itself is quite clear, and has a saline and disagreeable taste, and is often taken medicinally by the country people. Its specific gravity is 1·016. . . . .

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* "Analysis of a Saline Spring in a Lead Mine near Keswick" (App. 90).

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"The solid contents are contained in the following proportions in the imperial pint:—

Chloride of Calcium	87·67
„ Magnesium	1·53
„ Sodium	110·23
Sulphate of Magnesia	4·35
	203·78

Or in 1,000 parts by weight:—

Chloride of Calcium	9·86
„ Magnesium	·17
„ Sodium	12·40
Sulphate of Magnesia	·48
Water	977·09
	1000·00

"The peculiarity of this water is the large quantity of chloride of calcium which it contains. The largest amount recorded in any analysis I have been able to find is in one of the saline springs at Leamington, which contains 28 grains in the pint, or not quite one-third of the quantity in the Brandley spring; but the deficiencies of Sulphates of Magnesia and Soda will prevent it being used for the same purposes as those celebrated springs."

Another salt spring occurs just east of Manesty, but apparently not upon the line of the Brandelhow vein, but on that of a copper vein.

Helvellyn Lodes.—At the Wythburn Lead Mines three veins have been worked, two—the *Old Vein* and *Blue Rock*—with a N.N.E. and S.S.W. course, and the other having an E.N.E. and W.S.W direction, the former hading east, and the latter south. The Old Vein and the Blue Rock probably unite southwards. The galena of the former is in some places highly argentiferous. Several serpentinous dykes have been met with in the workings, the lodes being barren when traversing them; much of the "country" also is composed of very hard rock, and the difficulties of working are considerable. The course of the Old Vein and Blue Rock northwards, is somewhat obscure, but it seems probable that they run through the east end of the Browncove Crags, and unite. The east and west vein has only been proved for short distances.

Greenside Lode.—This constitutes the richest mine in the country. Its general course is but a very few points west of north, and its hade is to the east. The width varies considerably, there being sometimes strings of ore through a breadth of 40 feet; the west cheek is most constant, the east being very irregular. The veinstuff is chiefly quartz, in some places barytes is pretty abundant, and there is not much blende. There is an *average* of some 10 ozs. of silver to the ton of lead. The good ore-yielding ground lies between two dead tracts, on the north and south. On the north it meets, and for some distance runs alongside with a quartz felsite dyke, similar in all respects to the one described at page 34, and here it becomes quite "dead." Several east and west cross courses intersect the vein, and trail it westwards for a few feet only, they are all quite barren wherever proved.

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Grisedale Lodes.—In the Grisedale valley, east of Helvellyn, three lodes have been worked, some of the workings being very old.

The *Eagle Crag Vein* has an east and west course, hading to the south, though nearly perpendicular. The lode with a N.E. and S.W. direction, which meets the last just west of Eagle Crag, is called the *Clay Vein*, and though worked long since has been re-opened lately.

The *Ruthwaite Lodge* or *Tongue Vein* courses E.N.E. and W.S.W.; the workings on the west of the Grisedale Beck are mostly old, but upon the east side it has been opened into slightly of late years.

Hartsop Lode.—Some of the workings in this lode are very old, and it has been wrought at various periods. It courses N.N.E. and S.S.W., and hades to the west at about 65°. It contained some good ore, but in sops—rich in places, poor in others. There was but little blende with the galena.

(b.) *Copper.*

At the present time, I believe there is not one copper mine being worked within the area of 101 S.E.,* but in former times such mines quite constituted the celebrity of Keswick and its neighbourhood, as following extracts will show:—

Newland's Vale Lodes.—The principal copper lode has been that of *Goldscope*. Its course is from E.N.E. to W.S.W., to E. and W., across Scope Beck and Newlands Beck, but it appears to be several times faulted and thrown down on the east side by north and south lead veins. Its hade is to the south at an angle of from 50° to 60°. Several of the workings are exceedingly old, thought by some to go back to the time of the Romans (?). The old level was only 1 ft. 8 in. wide and 6 ft. high, with the incline of the lode itself, 50°. On the re-opening of the mine within a recent period many of the old tools were found, such as iron wedges and feathers, the former sometimes having chains attached to them and being four inches to more than a foot long; also some of the hammers minus their wooden handles. Another method of working seems to have been the following; holes were made about three inches or less in diameter, and filled with lime, water being then poured down a fine perforation made in the centre, the expansion of the lime split the rock all around. The veinstone was worked out in stopes of great regularity and exactness, all six inches long and the same deep, so square that a mortice might be fitted in without further chiseling. These processes broke up the ore-bearing rock into small pieces, about two inches square or less, and in the valley all around the old mine there are numerous heaps of such sized fragments, where they were picked and dressed.

The bearing part of the lode was about 150 fathoms from the

* Copper mines are still being extensively worked in the Coniston District (98 N.W.).

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low level mouth, just where a contra lode joins it from the north-east, beside the "Pan Holes." Neither vein contained much, far from this junction, but very rich veinstone was found *at* the Pan Holes. Twenty-two fathoms from the level mouth a small lead vein was cut, coursing north and south. No copper-working has been done here for the last 20 years. In High Snab Bank, west of Scope Beck, a little working has been done in this and some small veins joining it, but all a long time since. Several east and west veins, many of which seem to contain copper, traverse the craggy mountain on the east side of Newlands Beck.

A copper lode, worked in the reign of Queen Elizabeth, runs across the upper end of the Newlands Beck, and is thrown by north and south veins and faults at several places. Some of the old open workings are very evident at the surface. The hade is to the south at from 50° to 65°, or it is possible there may be two distinct lodes, one hading 50°, the other 65°. It is highly probable that the worked lode above Castle Nook Crags runs eastwards over Narrow Moor, and is continuous with the *Borrowdale Copper-lode* having also a southward hade of 65°, and which is worked out at the surface, and is faulted.

The *Dale Head Lode* has a N.E. and S.W. direction, and was first worked by some Cornish miners about 100 years ago. It contained some splendid green carbonate, but not much yellow copper.

The following are some of the older notices of the Keswick copper mines:—

"At *Newlands* also, which stands among the Mountains called *Derwent-Fells*, and other places near it, some rich veins of copper, with a mixture of gold and silver, were found in Mr. Camden's time by Thomas Thurland and Daniel Hochstetter, a German of Augsburg, which had indeed been discovered some ages before, as appears from the Close Rolls of King Henry III. n. 18, but were not wrought. So far is it from being true, that Tully hath said in his Epistles to Atticus, *'Tis well known that there is not a grain of silver* in Britain.' Nor would Cæsar have said that the *Britains* make use of imported copper, if he had known of the mines in this county, which afford now a plenty, not only for use, but exportation. *Keswick* also was formerly a place noted for mines (as a certain Charter given them by King Edward IV. proves), and is still inhabited by miners, as is also one of the Isles in the Lake adjoining by the same artificers from Germany."*

The following extract from Robinson's Natural History of Westmoreland and Cumberland (1709) gives an outline of the early history of these mines:—

"In the beginning of Queen Elizabeth's reign, there was erected a copper work near the town of Keswick,† the most famous at that time in England, and perhaps in Europe. The operators, managers, and miners were most of them Germans.

* App. 74.

† It stood by the river Greta, close to Calvert Bridge, opposite the present Brigham chool.

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The chief steward of the work was one Heckstetter, who by his books of accounts, which are most regular and exact, and all in large imperial paper, as well as by other writings I found under his hand, appears to have been a man of great learning as well as judgment in metals and minerals."

"The copper ore which kept these large furnaces at constant work was, for the most part, got in the veins upon Newland Mountains, the royalty whereof did then belong to the Earl of Northumberland."

"I find that some small quantities of ore were got upon Caldbeck and Cunnington* Mountains, and brought to the great work at Keswick, being a place most convenient, both for water and coal, which they had from Bolton Colliery."

"In our survey of the Mountains of Newland, we found 11 veins opened and wrought by the Germans; all distinguished by names given them, as Gowd-Scalp, now Gold Scalp, Long-Work, St. Thomas' Work, &c., of all which veins the richest was that they called Gowd-Scalp. We found the vein wrought three yards wide, and 20 fathoms deep above the ground level, which is driven in a hard rock a hundred fathoms, and only with pick-axe, hammer, and wedge, the art of blasting with gunpowder being not then discovered. For securing of this rich vein, no cost of the best oak-wood was spared, and for the recovering of the soles under level was placed a water-gin, and water was brought to it in troughs of wood upon the tops and sides of high mountains, near half a mile from the vein."

"The ore at the top of the vein, which appeared by day-light, was *sulphurous;* but in sinking deeper, the vein got more moisture and the ore improved in goodness."

"The ore got by the gin under level was so rich in silver that Queen Elizabeth sued for it, and recovered it from the Earl of Peircy for a Royal Vein."

"Most of the most judicious Miners and Chymists in England were concerned in the tryal, either as of the jury, or evidence. The verdict was given for the Queen; and, as the German books give account, a hundred tun of ore was entered upon by the Queen's Agents. This rich vein, and several more in the Mountains of Newlands, are now laid open and recovered by His Grace the Duke of Somerset, and likewise smelting-houses, furnaces, and all other conveniences are made ready by His Grace for setting forward a great work."

The following is from "Two Letters concerning several Copper Mines,"† bearing date 1684.

"*What quantity of unwrought Copper Ore is left upon the place?* . . . ."

"To the first query, I answer, That there is a heap of ore by Darwent, near Keswick;‡ and I suppose nobody lays claim to it,

* Cunnington = Coniston.

† App. 72.

‡ Copperheap Bay, on Derwentwater, is the spot from which the ore was sent across the lake to Keswick.

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but it is not worth anything; for being there so long, the weather has eaten out all the copper that was in it. . . . . All the ancient men that wrought at the smelting of it (copper ore) being dead; but it may be Mr. Hextecher's book will give some account of it. That book is in Mr. Anglionby's custody at Carlisle . . . ."

"The third question is, *What thickness and goodness the vein of copper ore is reputed to be of?*" In answer to which I say, It is reputed that the thickness of the vein at Gouldscope in Newlands was six feet; but for the goodness it cannot be known without comparison of divers sorts to see which is best, and no comparison can be made in things unseen."

Various lodes.—Other copper lodes in the map are of slight importance compared with those of Newlands. At the north end of St. John's Vale there are two east and west lodes, beneath Wanthwaite Crags and at Clough Head, both hading south, the one forming a faulted boundary to the Volcanic Series, and the other skirting for a part of its course the southern end of the quartz felsite of Wanthwaite Bank. Both are very gossany at the top. Another, running east and west, occurs on the hill-side above Thirlspot (east of Thirlmere) and has been slightly worked. A little copper-working was done 30 years since in the course of Birkside Gill, a little south of Wythburn.

Besides these copper lodes, above described, there are many east and west veins which appear copper-bearing, but may at the same time be of little or no value.

(c.) *Iron.*

The great demand for iron within the last few years has prompted the opening out of the occasional veins of hæmatite which traverse the mountains of this area. The chief of these ventures are in some veins with a general north and south trend, upon the hills between Buttermere and Ennerdale Lake.

Irony veins, with a north and south course, traverse Grasmoor and Ill* Crag. One with a north-west and south-east direction runs between Green and Great Gables, coursing south-eastwards by Sprinkling and Angle Tarns to Red Tarn and Wrynose in the one-inch sheet to the south.

There are a few traces of irony veinstone in some parts of Skiddaw, and a little north of Blencathra. Eastwards from Helvellyn, there is a strong vein running east of Kepplecove Tarn, across the lower end of Redtarn Beck to the foot of Nab Crag, and probably through a gap in the Glenridding Screes.

In Patterdale there are several well-marked hæmatite veins crossing Annstone Crag and Low Wood from north-west to south-east, but none have yet been opened out.

South of Wythburn turnpike there are some indications of smit iron-ore at the angle of the beck below the road, and south of Seat Sandal some iron mines have lately been opened, some of which are on the site of old workings.

* Wrongly spelt Eel Crag on the ordnance map.

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A chalybeate spring occurs on Threlkeld Common, just south of Rigghead. There is another mineral spring at Fieldside, near Keswick, and a third below Blencathra, north-west of Threlkeld.

(d.) *Barytes.*

Only one barytes mine is at present being worked within the area of this map. At the Forcecrag Mines at the head of Coledale, the vein runs nearly east and west and hades to the north at an angle varying from 65° to 75°. In some places it is 10 feet wide, in others not more than two feet. Occasionally the barytes is very free from iron, and in some parts—in sops—there is a good deal of galena and blende. East of High Force a thin manganese vein is crossed and some good ore extracted, but it is not at present (June 1874) followed beyond the lode.* Both the iron and manganese, which occur in places, are damaging to the value of the barytes.

Another barytes mine has been worked for a short time on the southern slopes of Skiddaw, beneath Carl Side. The vein, which contained some fair galena, courses N.W. and S.E., and hades to the south-west.

The Bannerdale lode (E. and W.) contains a great deal of barytes, but it has not been worked on this account. Another, on Ullswater, above Bleawick, has been slightly worked; its direction is a little east of north.

(e.) *Cobalt, Nickel, and Antimony.*

The so-called Cobalt mine, between Sail and Scar Crags (west side of Derwentwater), was scarcely a workable mine at all. The actual cobalt was in very small quantities, being found in the quartz in little specks, never so big as the uncut end of a pencil. No lead was found in the vein. Much expense was gone to in erecting smelting apparatus, and only 1 oz. of ore was actually got, though very little working was done.

Specks of nickel have been found in a quartz vein in High Snab Bank, north of Robinson.

The late Professor Sedgwick mentions in his *Letters* † (dated 1842) the occurrence of antimony, thus:—"The antimony works "in the Skiddaw Slate near the foot of Bassenthwaite Lake are, "as I am informed, now deserted." No trace of such workings is now to be found, but in the construction of the Keswick and Penrith Railway, there was discovered in blue drift-clay, at Troutbeck Station, a solid lump of antimony sulphide weighing 1 cwt., and unenclosed in any matrix. Mr. J. Wood, C.E., tested and proved its nature, as it was at first thought to be galena.

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* What manganese, however, is met with, finds a market.

† App. 21.

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CHAPTER X.

Plumbago or Graphite.

As the Plumbago Mine of Borrowdale is so well known by name, and the mode of occurrence of this mineral is of such interest, the subject will be treated somewhat in detail. See accompanying plans and section of the mine.

(a.) *Historical notices of the Mine.*

Mr. Otley, in an "Account of the Black Lead Mine in Borrowdale,"* says—

"Of the first discovery of this mine we have no account, but, from a grant made in the beginning of the 17th century, it appears to have been known before that time. The manor of Borrowdale is said to have belonged to the Abbey of Furness, and having, at the dissolution of that monastery, in the reign of Henry VIII., fallen to the Crown; it was by James I. granted to William Whitmore and Jonas Verdon; including among other things, *the Wad Holes and Wad, commonly called black cawke, of the yearly rent or value of* 15*s.* 4*d.* The said William Whitmore and Jonas Verdon, by a deed bearing date the 28th Nov. 1614, sold unto Sir Wilfrid Lawson of Isel, and several inhabitants of Borrowdale, all the said manor of Borrowdale, with the appurtenances of what nature or kind soever; '*Except* the wad holes and wad commonly called black cawke, within the commons of Seatoller, or elsewhere within the commons and wastes of the said manor.' In consequence of which reservation, the wad or black-lead mine, is held distinct from other royalties of the manor; one half thereof belonging to Henry Banks, Esq., M.P., and the other half subdivided in several shares. . . . . .

"The mine has been opened in different places where the wad has probably appeared at the surface; it has only been worked at intervals, and when a sufficient quantity was procured to answer the demand for a few years, the mine was strongly closed up till the stock was reduced. . . . . .

"On opening one of the old workings in 1769, it was found to have been carried to a great extent without the help of gunpowder; and this vein being pursued to the depth of 100 yards and upwards, much inconvenience was experienced in working it; to obviate which, in the year 1798, an adit or level was begun in the side of the hill, which, at the length of 200 yards, communicated with the bottom of the old workings. Through this level the water passes off, and the produce is brought out to be dressed, and on its mouth a house is built, where, when the mine

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* App. 82.

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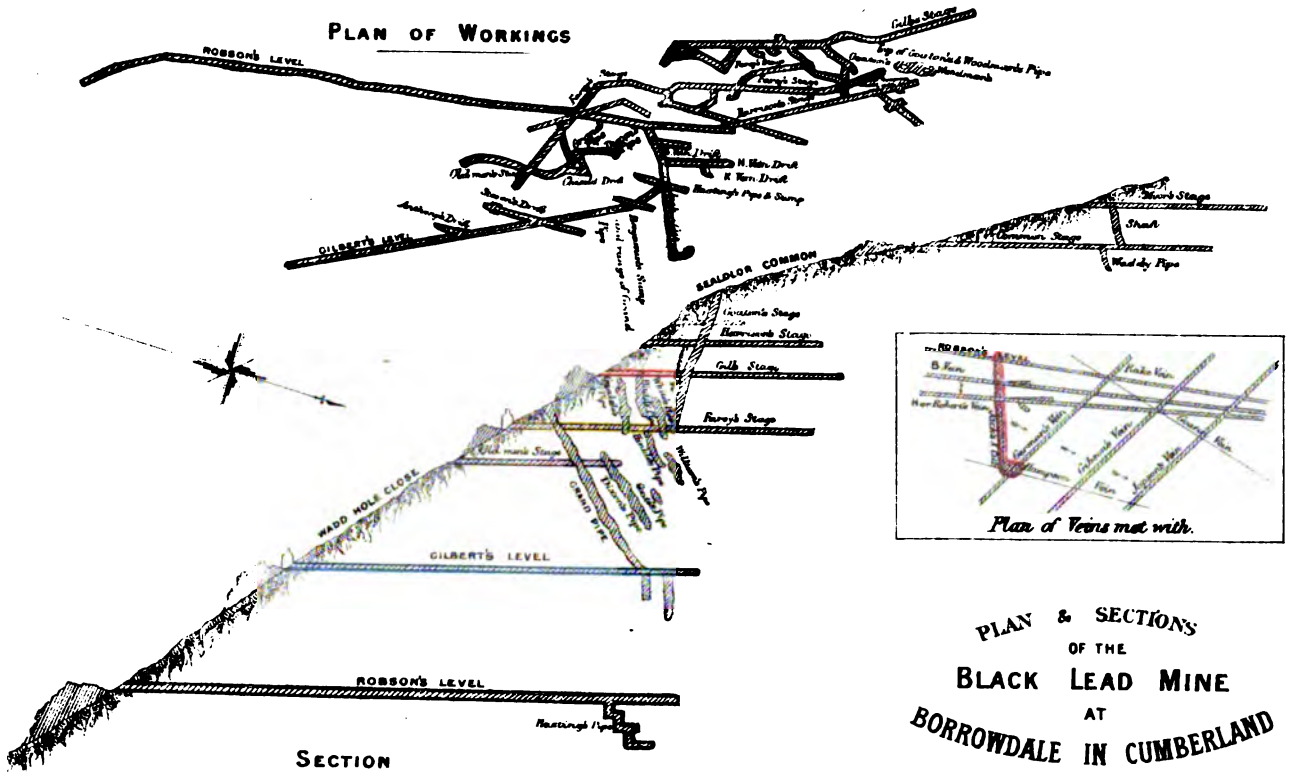

Dangerfield Lith. 22 Bedford St Covent Garden

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is open, the overseers dwell, and the workmen are undressed and examined as they pass to and from work. . . . . .

"This mountain consists principally of that kind of rock called greywacké, a stratum of a darker coloured stone runs through it, containing more iron, the joints strongly tinged with oxide of iron; this is traversed in various directions by strings or small veins exhibiting traces of wad, and it is generally at the intersection of two of these veins that the valuable bellies are met with; in one of which opened in 1803, upwards of 500 casks of the best quality were procured, containing about one hundredweight and a quarter each, besides a greater quantity of an inferior sort. Since that time two of these bellies have been met with, which have produced about 100 casks each.

"It comes from the mine in various pieces of an irregular shape, and of various sizes; some weighing a few pounds, but the greater quantity in smaller pieces; it requires no smelting or refining, the pieces are only cleared from any stony or extraneous matter which may adhere to them, and assorted according to the different fineness and sizes. . . . . .

"An Act was passed, 25th Geo. 2., cap. 10., by which an unlawful entering of any mine or wad-hole, or wad, or black cawke, commonly called black-lead, or unlawfully taking or carrying away any wad, &c. from thence; as also the buying or receiving the same, knowing it to be unlawfully taken, is made felony." In the preamble to this Act wad is stated to be "necessary for divers useful purposes, and more particularly in the casting of bomb shells, round shot, and cannon balls." . . . .

"The sp. gr. of the best wad, is to that of water as 2 to 1 nearly; the coarser is heavier as it contains more stony matter; black-lead is incapable of fusion, and was formerly thought to be incombustible; but it is found to be a carburet of iron, in the proportion of about nine parts carbon, to one of iron;* and being heated in a crucible with nitre, or other substances affording a great quantity of oxygen, its texture is weakened, and it is finally decomposed, the carbon disappearing and a little ochreous matter being left behind. By keeping it for some time immersed in melted sulphur, the black-lead becomes impregnated with sulphur; and being first reduced into slices, of about $\frac{1}{10}$ inch in thickness (the proper size for pencils), *it may be thus brought to the degree of hardness required.* Pencils treated *in this way may be known by the sulphureous odour,* and phosphorescent light emitted on rubbing the point upon a moderately heated iron.

"By an account drawn up in 1804 the stock then on hand was valued at 54,000*l.*, and the annual consumption about 3,500*l.*; the best black-lead was then sold at 35*s.* per pound; since that time the price has been from 30*s.* to 45*s.*, and no doubt the consumption has greatly increased. And this mine, which 200 years ago was valued at 15*s.* 4*d.*, has lately, on assessing the property tax, been estimated at 2,700*l.* a year."

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* *See* however, more recent analyses, pp. 65 and 66.

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In Hutchinson's History of Cumberland (1794)* occurs the following notice:—

"There are two workings, the lower one is about 340 yards above the level of the sea, the upper one about 390; the perpendicular depth of the lower is about 105 yards, and of the upper between 20 and 30 yards. There are no certain marks on the surface to direct the miner to the mineral. The strata of the mountains are very irregular and broken; and the black-lead probably was formed in the fissures of the rocks. There is no regular stratum of this mineral; it is met with in lumps and irregular masses. The miners generally work through a quantity of earth mixed with stones of various kinds, then a species of hard grey granite, and after that a dark blue stone of a softer nature, where they sometimes meet with it. Quarts and chrystles are found in the workings. The rock adjoining to this mineral is sometimes tinged as black as the mineral itself, to the depth of 2 or 3 feet. . . . . The best sort is now valued at three guineas a pound."

"October, 1792. The road-mines were very unsuccessful for some years past; but in the last year they met with the black-lead again in a pretty large quantity, but of the inferior quality, of which in a short time the miners procured about five tons. The mineral is described as lying in the mine in form resembling a tree; it hath a body or root, and veins or branches fly from it in different direcrent directions; the root or body is the finest black-lead, and the branches at the extremities the worst, the further they fly. The veins or branches sometimes shoot out to the surface of the ground. It is sometimes found in sops or floats, in a body without branches. A blue rock lies on each side of the mineral, and sometimes there is a wet sludge between the rock and the black-lead. The metal in the low mine lies in two veins, one crossing the other; where they cross is the main body, and the best black-lead; and these veins fall perpendicular for 60 fathoms in depth, the blue rock on each side; at the end of 60 fathoms they found the end of the cross vein, and a large sop of the mineral, which came out as if it had been in a wrought basin, the form of the black-lead and the rock were so equal."†

In Robinson's "Natural History of Westmoreland and Cumberland" (1709), Chapter XIII., "Of Mundick Metals, but more especially of Black-lead, or Wadd; its Nature and Uses, &c.," the following curious notice occurs:—

"Its composition is a black, pinguid, and shining earth, impregnated with lead and antimony. This ore is of more value than either copper, lead, or iron.

"Its natural uses are both medicinal and mechanical. It's a present remedy for the cholick; it easeth the pain of gravel, stone, and strangury; and for these and the like uses it's much bought up by apothecaries and physicians, who understand more of its medicinal uses than I am able to give account of.

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* App. 77.

† "We acknowledge our obligations to Mr. Crosthwaite and Mr. John Ladyman for much information.—The Editors (of the History of Cumberland)."

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"The manner of the country peoples using it, is thus; first, they beat it small into meal, and then take as much of it in white wine, or ale, as will lie upon a sixpence, or more if the distemper require it.

"It operates by urine, sweat, and vomiting. This account I had from those who had frequently used it in these distempers with good success; besides those uses that are medicinal, it hath many other uses, which increase the value of it.

"At the first discovery of it the neighbourhood made no other use of it but for marking their sheep, but it's now made use of to glazen and harden crucibles, and other vessels made of earth or clay, that are to endure the hottest fire; and to that end it's wonderfully effectual, which much inhaunceth the price of such vessels.

"By rubbing it upon iron-arms, as guns, pistols, and the like, and tinging of them with its colour, it preserves them from rusting.

"It's made use of by dyers of cloath, making their blues to stand unalterable; for these and other uses it's bought up at great prices by the Hollanders and others.

"The lords of this vein are the Lord Banks and one Mr. Hudson. This vein is but opened once in seven years, but then such quantities of it are got that are sufficient to serve the country.

"This Mundick Ore having little of sulphur in its composition will not flow without a violent heat. It produces a white regulus, shining like silver. It cannot be made malleable."

To these notices regarding the history of the mine, I may add, that according to tradition, the first discovery of the valuable deposits of plumbago was made by the uprooting, in a storm, of a large ash tree, growing upon the spot where the grand pipe comes "to day;" this spot lies between Farey's and Gill Level.

(b.) *Geological Position.**

The geological conditions under which this mineral occurs are somewhat curious. The extracts already given will sufficiently show its general manner of occurrence—in pipes, strings, and sops. If I have understood the geological structure of the hill-side correctly, the plumbago occurs in close connection with a dyke of highly altered diorite lying between two other masses of intrusive blue trap (diabase) of a compact character. The diorite is much penetrated by quartz strings, and in several places on the hill-top impure plumbago may be seen in it in nests, mixed up with veiny material. One, if not both sides of the diorite are bounded by

* I am much indebted to the proprietors of the Borrowdale mine (Borrowdale Plumbago and Lead Mines Company) for the ready help they have afforded me. In the present hands the mine will undoubtedly have a fair trial given to it, and it is hoped that some discoveries may be made, which will throw light upon the obscure question of the origin of graphite in such cases as these. At present (April 1875) very little new ground has been broken, and it should be remembered that in past times the workings have sometimes been carried on for years without meeting with any of the larger rich masses.

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veins; the west side by a lode (Gill vein) hading east at about 65°, and no plumbago has ever been *worked* to the west of it. Other barren veins are met with in the workings, and their relations to one another are indicated in the small plan on Plate VIII.

The diorite cannot be traced across the Fell to Honister Pass, and appears to extend in a N.N.W. and S.S.E. direction for not more than one-third of a mile. Although, however, plumbago does occur in this diorite, has been met with in small quantities in the workings of Common stage and Moor stage, and the upper and rich part of Goaton's Pipe appears to have traversed this rock near its southern boundary, yet have all the principal pipes been found in connection with the very compact blue diabase, and the highly altered ash rocks adjoining and very similar to it. A careful examination in various levels shows this to be the case, although previously, from mere surface examination, I had thought that the plumbago mostly occurred in the diorite. The diabasic rocks are often full of crystals of iron pyrites, and these I noticed in almost every case around the pipes. The pipes themselves are seldom more than two or three yards in their longest diameter, and one yard in their shortest, though extending to considerable depths; they often seem to come on very suddenly, and, while surrounded by the very compact diabase, are themselves made up of an irregular "waddy" breccia, mingled with strings and bunches of quartz. Sometimes thin sheets of plumbago occur along the joint lines of the hard rock, and this is regarded as a promising *lead* to something better.

The ash-rock all about these intrusive traps is very much metamorphosed, and it is rather doubtful whether or not there may be other intrusive masses of trap on the steep hill-side just south-west of the Borrowdale Yews.

The following are the results of a microscopic examination of the diorite (?) and diabase :—

Diorite (?) (Fig. 24, Plate III.).

This is evidently a much altered rock. There are numerous felspar crystals, all small, and some acicular, largely replaced by a yellowish green mineral which abounds in all directions, and is often crystallized in comb or fan-shaped expansions. Since this mineral is also dichoric in many parts and exhibits in certain sections a red colour, it is probably chlorite. Some of the fibrous green mineral may be altered hornblende. The felspar is too much altered to determine its species (orthoclase or plagioclase). Scattered quartz occurs, into spaces of which acicular crystals project. In some instances, there shoot out from the sides of these crystals, finely-pointed greenish needles, occasionally branching, and stellate groups of such needles are not uncommon in the quartz. Magnetite, often appearing in the slice as square sections, is present; and plumbago occurs either in black specks or forming a light blue-black, nebulous haze. On examining these clouds of small particles with a high power, they are found to consist of minute, semi-rounded or oblong granules from the $\frac{1}{5000}$th to the $\frac{1}{10000}$th of an inch in diameter, but many show a very

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marked six-sided form, so that it seems probable that we have here some of the minute hexagonal crystals of graphite (plumbago), the oblong forms representing the short prism. The *square* sections of magnetite crystals are markedly different from these graphitic cystalline grains.*

Intrusive Trap (Diabase) on west side of Diorite.

The base, which is in great part felsitic, contains many finely acicular crystals with a great deal of scattered magnetite. Small augite crystals and grains occur, some of them showing a twin structure. The green pseudomorphic mineral is far less plentiful than in the last. There are a few quartz spaces in this rock also, and into them acicular crystals project. Some of the larger felspar crystals appear to be triclinic, but all are much altered.

(*c.*) *Chemical Composition.*†

The origin of Plumbago or Graphite, in nature, has from time to time been discussed, Haidinger, G. Rose, Dumas, Despretz, Jacquelin, and others, having advanced various opinions. The subject is, however, involved in so much doubt, and the evidence which has been brought forward is so conflicting, that, for the present, at all events, the question is still an unsettled one.‡ The mineral was regarded as a Carburet of Iron until 1825, when Vanuxem showed that the iron was not an essential constituent; according to Rammelsberg, however, Karsten was the first to point this out.

The following are some analyses of Cumberland Graphite:—

C. Mène, *Comptes Rendus*, lxiv., 1091—1867.

	Carbon.	Vol.	Ash.	Sp. gr.
1.	91·55	1·10	7·35	2·3455
2.	84·38	2·62	13·00	2·5857
3.	78·10	6·10	15·80	2·4092

Composition of 100 parts of the ash.

	SiO_2.	Al_2O_3.	FeO.	MgO. CaO.	Alk. & Loss.
1.	52·5	28·3	12·0	6·0	1·2
2.	62·0	25·0	10·0	2·6	0·4
3.	58·5	30·5	7·5	3·5	—

Schräder—cited in Bristow's Glossary of Mineralogy.

Carbon - - - -	85·25
Iron Protoxide - - -	5·80
Silica - - - - -	3·50
Alumina - - - -	2·30
Oxide of Titanium - - -	3·15
	100·00

* At a future time I hope to make a more extended microscopical and chemical examination of the rocks associated with the plumbago.

† I am indebted to my friend and colleague, Mr. Frank Rutley, for help in this part of the subject.

‡ Professor Sedgwick suggested the possibility of the plumbago, in this case, being derived from the underlying Skiddaw Slate. App. 91.

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Vanuxem—Phil. Mag., vol. lxviii. p. 161.

(I.)

Carbon			88·37
Water			1·23
Residue by incineration, colour yellowish brick red.	10·4	Silex	5·10
		Allumine	1·00
		Oxides of iron and manganese	3·60
		Loss	·70
			100·00

(II.)

Carbon			61·27
Water			5·33
Residue by incineration, colour of a dirty yellowish red.	33·4	Silex	10·10
		Allumine	3·20
		Oxides of iron and manganese.	20·00
		Loss	·10
			100·000

No. I. was a specimen of great purity, and No. II. an impure specimen.

I am indebted to W. Salmon, Esq., for the following analysis recently made by Dr. Percy; the specimens analysed were said by Mr. Salmon not to be the purest (commercially):—

Carbon	86·69
Ash	11·17
Water	2·14
	100·00

The above analyses* acquire additional interest when viewed in connection with the artificial formation of Plumbago; the following is an extract from a letter of Faraday's to De la Rive (1825).†

"I must not forget to tell you how we formed our alloys. . . . . Fuse iron in small pieces with charcoal powder. If the button produced is malleable break it up, and re-fuse it with more charcoal. In this way a carburet of iron will be formed which has its place between steel and plumbago. It is fusible, when broken has a dark-grey colour, and is very highly crystalline. It is so brittle that small pieces of it may be rubbed to powder in a mortar . . . . . Whilst making the carburet above-mentioned, we also succeeded in forming plumbago; but I am afraid this artificial production of it will not be very useful in its application. If iron be heated highly, and long enough in contact with charcoal, plumbago is always formed. I have some buttons of metal here, weighing two or three ounces, that appear to be solid plumbago. The appearance, however, is deceitful, for it is only on the surface, and to the depth perhaps of $\frac{1}{40}$th of an inch that

* See also tables of analyses of foreign graphites in Dr. Percy's Metallurgy (Fuel, &c., 1875), p. 105.

† Bence Jones' *Life of Faraday*, vol. i. p. 291; "Experiments on steel made in "conjunction with Mr. Stodart."

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the plumbago has been formed. The internal part is composed of the crystalline carburet before mentioned. What is plumbago is very good, and marks excellently well; and though we have never yet been able to fuse powdered plumbago into a mass,* yet I think, if it were required to form it in a compact state to work up into pencils, it might be done by imbedding plates of iron, about $\frac{1}{20}$th of an inch thick, in charcoal, and heating intensely for a long time. This we have not yet had time to try, but intend to do so."†

The present price (Jan. 1876) of pure Borrowdale plumbago, is about 40*s.* per pound. The following extracts from Dr. Percy's Metallurgy (Fuel, &c., 1875), p. 103, are important in connexion with this subject:—

"Graphite suitable for the manufacture of the best black-lead pencils is of rare occurrence, and, consequently, fetches a high price. No graphite has been so much in request for this purpose as that of Borrowdale, in Cumberland; but graphite adapted to the manufacture of crucibles may be procured in abundance in various localities at a moderate price. It is the peculiar state of aggregation which gives value to the Borrowdale graphite, and not its purity; for, according to Karsten, it leaves on combustion not less than 13·3 per cent. of ash; whereas some of the Ceylon graphite, which is of comparatively small value for pencils, contains only traces of foreign matter. . . . .

The suitableness of graphite for crucibles depends, not only on the nature and proportion of the associated foreign matter, but also on the state of aggregation of the graphitic carbon. . . This is a question which must be decided by an actual trial."

Plumbago is said to occur in the Bannerdale Lode, to the north of Blencathra. This vein has, however, been very slightly worked, and though there appears to be an irony carbonaceous mineral adhering to the sides of the lode and sparingly distributed, it seems probable there is no genuine, good plumbago; nevertheless some of the mineral was worked for grate-polishing, and Bannerdale pencils are said to have been made. The vein contains a great deal of barytes and some galena; its course is nearly east and west, and it traverses rocks of spotted schist.

* By Brockedon's patent, introduced of late years, powdered plumbago is converted by pressure into a compact solid, suitable for the manufacture of pencils.

† I am not aware, however, that this was ever carried out.

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CHAPTER XI.
CLEAVAGE.*

In Plate IX. the direction taken by the anticlinal and synclinal curves, both of the true dip and cleavage dip, is shown. Though the area for comparison is but small, the following points are worthy of notice—

1. The cleavage-dip in the Skiddaw Slates, which are often much contorted and crumpled, is very constant both in direction and amount, the former being for the most part south-east and the latter averaging between 55° and 60°. Only two instances can be placed on the map (Plate IX.), in the Skiddaw Slate area, of anticlinals in the cleavage. 2. In the area occupied by the Volcanic Series, where the true bedding is much more regular and only thrown into large curves, the anticlinals and synclinals in the cleavage are well-marked and range for considerable distances. In one instance, about Watendlath, a cleavage synclinal nearly corresponds for a part of its course with an anticlinal of the strata, but the latter ceases westwards long before the former. The long cleavage anticlinal and synclinal further south certainly do not seem to correspond with any marked reverse curves in the true bedding. 3. While the strike of the cleavage among the Volcanic Series has the same general N.E. and S.W. course as that among the Skiddaw Slates, the average amount of the dip is decidedly greater, being over 70°, whereas in the Skiddaw Slates the average is less than 60°. 4. Among the metamorphosed Skiddaw Slates, the planes of cleavage and foliation seem often to coincide. 5. While cleavage is generally confined to the softer and more finely-grained rocks, seldom occurring among the sandy beds of the Skiddaw Slates or the contemporaneous traps of the Volcanic Series, yet are many ashy breccias of the latter group, and some even of the traps, affected by it occasionally, and there is one instance of a narrow quartz felsite dyke, on Kirk Fell, being highly cleaved, while the altered ash beds around are not so. 6. The elongation of the ashy fragments along the planes of cleavage is often well-marked.

I think then it may be concluded that the Skiddaw Slates and the Volcanic Series were both cleaved at the same time and by a pressure acting in a N.W. and S.E. direction; also that much of the foliation was either an extension of the same process or took place subsequently in the direction of the cleavage planes, as those of least resistance. This intense lateral pressure, while producing cleavage both in the Skiddaw and Volanic Series, affected the two formations differently as regards contortion; in the one case it crumpled the beds, except where much banded by sandstone; in the other it threw them merely into a series of low curves. Prof. Sedgwick noted this in 1836 (App. No. 16), and says, "this fact might appear inexplicable, but we find a solution of our difficulty in the enormous irregular masses of hard unbending felspathic and porphyritic rocks, imbedded in, and so intimately mixed with, the green quartzose slate."

* App. 25 and 36.

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Map to show direction of Anticlinals and Synclinals in the True Dip and Cleavage Dip

—— *Anticlinal* } *in True Dip* —— *Anticlinal* } *in Cleavage Dip.*
----- *Synclinal* } ---- *Synclinal* }

-.-.- *Rough boundary between Skiddaw Slates* (b^2) *and Volcanic Series* (b^3)

S. Syenite C. Basement Conglomerate

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CHAPTER XII.

ORIGINAL RELATION OF THE FORMATIONS TO EACH OTHER, AND THEIR PHYSICAL HISTORY.

It is very unfortunate that in the whole of this area there are no *clear* sections showing an unfaulted boundary between the Skiddaw Slates and the Volcanic Series. One instance has been mentioned of the interstratification of a thin band of Skiddaw Slate among the traps of Eycott Hill, and Mr. Aveline has found at Black Combe, in the south-western part of the lake district, a very decided alternation of Skiddaw Slate beds with those of the Volcanic Series. Quite lately, also, Mr. Dakyns and I have met with a very complete passage between the formations in the district immediately west of Shap; in one place bands of bedded ash among the mass of the Skiddaw Slate, and in another, thin beds of Skiddaw Slate fairly interbedded with the lower part of the Volcanic Series. So that there is little doubt but that the two formations are conformable to one another, and that the apparent unconformity across the area of 101 S. E. is due, as already described, to the faulting of the two series together.*

Nevertheless, along this generally faulted junction, there are signs of a passage between the two formations. Thus, about Clough Head, between the southern margin of the St. John's quartz felsite and the volcanic beds of the Wanthwaite Crags, there occur some alternations of ash with Skiddaw Slate, the whole being much altered and probably separated from the mass of the Volcanic Series by faults. Indeed, there are not wanting indications that possibly the two areas of the St. John's quartz felsite represent a highly metamorphosed series of alternating volcanic and slaty beds, lying at the junction of the two formations, for occasionally—as on Wanthwaite Bank—ashy deposits occur in the *midst* of the quartz felsite, and the occurrence of a band of Skiddaw Slate running through the felsite of Low Rigg—west of the church— has already been noticed.

Again, on the hill-side, west of Grange, I have traced a thin band (four or five feet) of volcanic rock, for nearly half a mile, interbedded with the Skiddaw Slates, although the junction of the two formations at the foot of the crags above is undoubtedly a faulted one. It would seem also that the eastern boundary of the syenitic granite of Buttermere and Ennerdale, agreeing so closely for much of its course with the strike of the volcanic beds above, and being faulted in common with them, may represent the coming on of a junction series of strata, which have since been highly metamorphosed.†

* In 101 S.W. conglomeratic ash lies upon and overlaps the gritty beds of Latterbarrow, the uppermost slates of Skiddaw being absent. I feel convinced, however, that this unconformity is but local.

† For the discussion of such *theoretic* points as these, see the author's memoir "On the Granitic, Granitoid, and Associated Metamorphic Rocks of the Lake District," the various parts of which are now being brought before the Geological Society.

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The strata exposed in Trout Beck, west of Mell Fell, and in Matterdale Beck, are probably near the junction of the two series, the beds in both cases uniting, in some respects, the characters of the two formations.

With regard to the Basement Conglomerate and Carboniferous Limestone, there is clear proof that they are unconformable to the older formations, and that an immense amount of denudation had taken place, both of Skiddaw Slates and Volcanic Series, before their deposition.

The physical conditions under which these various deposits were formed must now be discussed, commencing with the oldest period represented.

(a.) *Skiddaw Slate Period.*

The nature of the deposits and the character of the scant remains of life found in them, point to marine conditions in a more or less shallow sea. The thickening of the sandy and gritty beds westwards may indicate land in that direction, very shallow-water conditions being occasionally met with. In the absence of any limestone beds it would be rash to infer that the fossils at present known represent truly the life of the period, which in more favourable situations may have been as plentiful as in some modern seas.

(b.) *Volcanic Period.*

The close of the Skiddaw Slate period was marked, not by any *general* upheaval and consequent denudation,* but by a gradual coming in of volcanic action over the old sea-bed. The earlier volcanic outbursts were submarine in character; lava flowed over the sea-bottom, and ash, if thrown fairly above the water, fell back and was interstratified with deposits of mud and sand (as shown at Eycott Hill, in the Black Combe country, and near Shap, &c.). It seems probable, however, that this state of things did not long continue; volcanic action was accompanied, as it so generally is at the present day, by a gradual upheaval of the old ocean-bed. A volcanic cone or cones appeared above the sea; the latter became more shallow, partly from the materials accumulating in it, and partly by the slow elevation taking place. I think there is little doubt but that one of the main volcanic centres of this particular district was nearly on the site of the modern town of Keswick, the round boss of intrusive dolerite forming Castle Head, representing the solidified lava deep below the old crater; the eruptive point, from which flowed the lavas of Wallow Crag, was, of course, far above.† (Plate X.)

As the Castle Head rock is probably in connexion with that of Friar's Crag, and this last may strike across the lake a little south of Derwent Isle to unite with that of Rosetrees, it is quite likely that the point of eruption changed its position along this line,

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* See note on preceding page.

† How far above, it is impossible to say, since the throw of the fault (*f*) is unknown. The reader will bear in mind that the Volcanic Series once extended over the area of Skiddaw Slates, now exposed by denudation.

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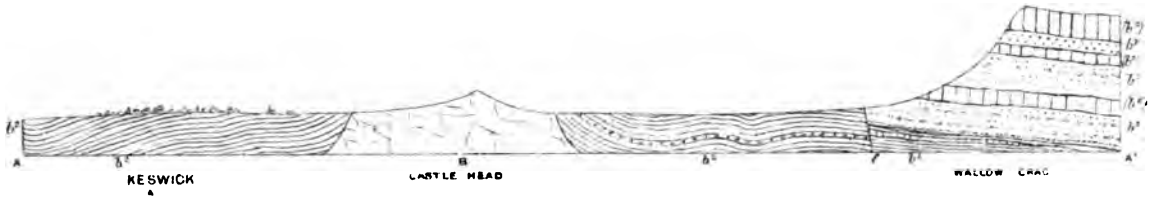

A to A' Section from Greta Hall, Keswick, to Wallow Crag Scale, 3 Inches to 1 Mile.
b^2 Skiddaw Slate. b^3 Ash and breccia. (b^2) Lava beds. B Dolerite, probable source of the lava-flows, f Fault, produced most likely, long after volcanic action had ceased.

Dangerfield, Lith., 22, Bedford St., Covent Garden

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which may also extend farther to the east, though now concealed by a covering of Drift.

That this was the only volcano in the *whole* district is not likely, but that it represents the centre from which the thick lava-flows of Bleaberry Fell and *perhaps* of Eycott Hill proceeded, is, I think, almost certain. Other of the intrusive bosses and dykes among the Skiddaw Slates may be the roots of subsidiary vents, and some of the intrusive masses among the volcanic beds themselves—such as the diabase in Sourmilk Comb, below Base Brown, and perhaps that in connexion with which the plumbago occurs—probably represent the centres from which *some* of the *upper* beds of the series were distributed. The felsitic and syenitic masses of St. John's and of Buttermere and Ennerdale were most likely—for reasons shortly to be mentioned—not volcanic centres in the ordinary sense of the term.*

It is a matter of no little difficulty to reconcile the wide-spread and oftentimes beautifully regular bedding of the ash, with a wholly sub-aerial origin. Yet the *total* absence of ordinary sedimentary deposits (except quite at the base) and of fossils, would seem to shut out the idea of sub-marine deposition, although at the same time it is possible to conceive such a continued showering forth of ashy material over a limited sea-area that no interstratifications of mud, sand, or limestone could occur, and that life could not exist in the waters. Nevertheless it should be remembered that showers of volcanic material falling upon the land assume frequently a wonderfully perfect stratification, especially when the material is fine and mixed with water, as is so generally the case in great eruptions, where deluges of rain accompany the outbursts. Upon the sloping flanks of the Solfatara, near Naples, fine trachytic ash presents a very closely-bedded structure, the various laminæ containing the impressions of grass and leaves. Deluges of ash-mud must have been as common in old times as in modern, though none of the old Cumberland ashes have at present disclosed to us any traces of the land vegetation, if any such was permitted to grow in the intervals of eruption.

It may be that large sheets of water were confined between or near some of the volcanic cones, or that crater-lakes occasionally occupied considerable tracts; in such cases all the sedimentary deposits would be ashy in nature, and if the eruptions were frequent from the surrounding vents, or if noxious vapours ascended through the waters, animal life would have little chance of existing. It certainly seems probable that *some* of the well-bedded ash was formed sub-aqueously, but the absence in any quantity of *well-rounded* ashy material precludes the idea of anything like open marine action. The regularity and constancy of the dip, especially when the larger curves formed by subsequent disturbance are left out of consideration, seem at first sight another difficulty in the way of a full acceptance of the sub-aerial theory, though even this

* Dr. Nicholson, in a paper in 1869 (App. 53), *was* disposed "to look upon the "igneous masses in question as the roots of the ancient vents."

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receives explanation if we suppose that the great centres of eruption were few or far between.* After all, the district in which the volcanic rocks occur, is so very small, that one may walk from one end of it to the other in a single day, and many a modern volcano spreads its ejecta over a far wider area than this.

In searching for the chief volcanic centre or centres, the presence of the old lava-flows would seem the safest guide, as ash may be thrown up to a great height and fall over very wide areas.† Now, it is a very striking fact that over the whole main extent of this volcanic series, from Keswick to Coniston—some 14 miles in a straight line—beds of lava are almost wholly confined to the lower parts of the series, and occur in greatest force within a distance of some six or eight miles from Keswick. From which we must conclude,—1st, that the earlier eruptions were more characterised by the ejection of lava, and the later by the almost sole ejection of ash; 2nd, that if other centres of eruption gave vent to a series of lava-flows in the *southern* area they have been hidden from view by the more recently deposited ash; 3rd, that the Keswick volcano and its subsidiary vents form certainly *one* well marked centre, from which lava may have flowed southwards, at least as far as Borrowdale (six or seven miles), eastwards as far as Helvellyn (six miles), north-eastwards to Eycott Hill (eight or nine miles), and very likely north-westwards and northwards to Cockermouth and the district beyond Skiddaw. Several of the subsidiary vents may have been at some little distance from the main Keswick one, and thus there is no difficulty in accounting for the distribution of the lava-beds, even if the distances named above were not often very far exceeded by some of the flows of existing volcanoes.

It is quite impossible to form any idea of the length of time during which this volcanic action may have lasted. The non-appearance of anything like decided breaks in the series, perhaps points to continued and severe eruption over a comparatively short period, these eruptions being partly co-temporaneous with the submarine volcanoes of North Wales, where marine shell-bearing deposits are interstratified with the purely volcanic, and the ash-beds themselves contain marine fossils.

(c.) *Upper Silurian Period.*

Although no rocks of this period occur in the area of 101 S.E., a word must be said about them in order that we may understand what has to follow. Mr. Aveline's work in the south of the district has clearly proved the complete unconformity of the Coniston Limestone and overlying beds, to the Volcanic Series. This unconformity probably represents the time during which the

* Walking from the summit of the Alban Mount to Frascati, near Rome, a distance of six or seven miles, I remember specially observing the very uniform dip of the ash away from the old volcanic centre, thrown into curves, however, in some parts not far from Frascati by subsequent disturbance. An ash-breccia, close to Frascati railway station, strongly reminded me of the Cumberland volcanic breccias.

† Some of the ash thrown out from Vesuvius in the eruption of 1794 fell at a distance of 140 miles from the mountain.

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volcanic land-area was being depressed beneath the Coniston Limestone and Upper Silurian sea. The latest volcanic efforts may have been made during the deposition of the Coniston Limestone, for it contains interstratified and fossiliferous, ashy-looking beds, and a probable lava-flow.* Then, over the whole district, during very long periods, there were deposited upon the series of volcanic strata a great thickness of Upper Silurian beds, amounting, Mr. Aveline estimates, in the Kendal district, to at least 14,000 feet. Thus, at the close of the Upper Silurian period, there is every reason to believe that, in the northern part of the present Lake-district, the Skiddaw Slates were buried deeply beneath the whole of the Volcanic Series—from 12,000 to 15,000 ft. in thickness—and the Upper Silurian strata—perhaps 14,000 ft.; making altogether some 25,000 to 30,000 ft. of rock above the topmost beds of the Skiddaw Slate.

(d.) *Old Red Sandstone Period.*

Most likely the greater part, if not the whole of this Period, is unrepresented by deposits in the Lake-district, the so-called Upper Old Red being probably but the basement bed of the Carboniferous Series.† The reason for this absence of Old Red rocks seems clear. Immediately succeeding Upper Silurian times came a period of gradual upheaval and unprecedented denudation; nothing was added to the country, but huge thicknesses of strata were carried away by the denuding agents and deposited elsewhere.

It was at the commencement of this epoch of disturbance and denudation, when the Skiddaw Slates lay most deeply buried beneath the surface, that the effects of intense pressure and internal heat must have been greatest upon these strata. Then, probably, it was, that the masses of granite were formed—perhaps in great measure out of the beds of the Skiddaw Slate and Volcanic Series—and ate their way upwards among the superior strata, metamorphosing the neighbouring rocks, and sending dykes and quartz veins amongst those still higher, as all were contorted and cleaved by the *intense lateral pressure* called into play during the slow upheaval of the district.‡

Certain it is that all the igneous masses were not formed or did not solidify at quite the same period *or* under quite the same circumstances. Thus, the difference already pointed out in the microscopic structure of the Ennerdale and Buttermere syenitic granite and the St. John's quartz felsite are striking; in the former case the quartz is interstitial, not generally crystallized (Fig. 6, Pl. I.); in the latter, the quartz occurs in small crystals (Fig. 5, Pl. I.)

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* This probable lava—west of the Shap granite—is a true felstone and quite unlike the older lavas of the district in character.

† Explanation of Quarter Sheet, 98 S.E., p. 16.—Mr. Goodchild.

‡ Mention has already been made of the way in which quartz veins seem to have insinuated themselves among the strata while contortion was going on, or frequently to have crept along the cleavage planes.

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imbedded in a felspathic base; while again, in the Armboth and Helvellyn dyke, probably proceeding from the St. John's felsite, the quartz crystals are similarly imbedded but much *larger* (Fig. 4, Plate I.). In all these cases the quartz contains liquid cavities with vacuities, and it remains a subject for future investigation, to determine if possible—in the manner Mr. Sorby has so ably shown us*—the relative depths and pressures under which these various masses may have solidified, and the relation they may bear to one another.†

When these facts of change at great depths are considered, it is certainly not to be wondered at if, in studying the rocks as they are now exposed to our gaze, we find Skiddaw Slate altered into Mica Schist, and felspathic ash into semi-crystalline Felstone. Another point also should be remembered when we are called upon to decide between the possibility of certain beds being metamorphosed along the main line of strike, or such beds having been originally what they now appear. The general strike of the strata over the whole district being S.W. and N.E., and the cleavage having generally the same strike, it would seem that the lateral pressure producing both sets of phenomena acted in a N.W. and S.E. direction, and in all probability the greatest amount of metamorphism would be effected along the axis of upheaval in a direction S.W. and N.E. As a matter of fact, we find the great mass of Eskdale granite stretching from the district, south of Ravenglass, north-eastwards, to the head of Wastdale, for a distance of more than 14 miles; while the series of N.E. and S.W. dykes crossing Longstrath may point to a continuance of the same axis deep below, and the highly altered rocks of the head of the Thirlmere valley, below the Helvellyn range, between Wythburn and Dunmail Raise—eight miles E.N.E. from Wastdale Head—may be the result of a granitic mass not far below, upon the same great line.‡ If then this axial line of intense metamorphism existed, it is not to be wondered at that the overlying rocks along that line should show more signs of alteration than in most other parts, and this alteration would be rendered *most evident* among the finer-grained deposits, producing what at *first sight* may now seem like *beds* of felstone interstratified with highly altered yet readily recognizable coarse ash.§

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* *Quart. Journ. Geol. Soc.*, vol. xiv. p. 453.

† This, since the above was first written, I have endeavoured to do, as far as my limited unofficial time would permit, and the result has been communicated to the Geological Society (Quart. Journ., vol. xxxi. p. 568). Dr. Nicholson, in a paper on the Shap Granite (App. 49*a*) states his conviction that the Lake District Granites are truly eruptive, and that none "can be shown to be in any way connected with any axis of elevation or disturbance."

‡ The formation of great faults *since* the metamorphism, such as the north and south fault along the Thirlmere Valley, may often bring highly altered beds against masses of rock but little altered.

§ I am fully aware that some people, only casually glancing at the rocks while passing through the district, would come to very opposite conclusions, but if they cannot credit the evidence brought forward in these pages or fall in with the line of argument, I can only beg them to withhold judgment until they shall go as thoroughly over the country as it has been my good fortune to do.

Mr. J. G. Marshall supposed the *whole series* to have been "originally soft "stratified deposits" since altered, variously, according to fusibility, into porphyritic or hardened stratified beds (App. 38).

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To this long period of upheaval and disturbance, and perhaps especially to its earlier part, I would refer the greater number of those faults that range between N.E. and S.W. and E. and W.; while the N. and S., and N.W. and S.E. faults are probably of younger date, and they are usually found to shift the former. Thus the present faulted boundary between the Skiddaw Slates and the Volcanic Series was the result of the earlier set modified to a considerable degree by the later. Of course it is not meant that faults having quite opposite directions may not sometimes have been produced at or about the same time, the piece of country between them being thrown down or up, just as we may often see on a small scale among the numerous cracks in a large, thick sheet of ice.* The classification of faults according to direction is, also, in a mountainous country, rendered somewhat difficult, on account of the not unfrequent *apparent* change of course in passing across steep and lofty mountains.

These then were the phenomena produced during the great unrepresented Old Red period—formation and partial intrusion of igneous masses; extensive metamorphism; elevation along a N.E. and S.W. axis,† accompanied by contortion, cleavage, foliation, and faulting of the strata; penetration among the beds, of quartz veins and igneous dykes; and, at the surface, an enormous amount of denudation.

The last point—denudation—must be briefly considered, as it gives us an idea of the great length of time which passed, between the deposition of the Upper Silurian and the Lower Carboniferous. The Basement Conglomerate rests sometimes upon Skiddaw Slate, sometimes upon the Volcanic Series, and sometimes (in the country to the south) upon the Upper Silurian. Hence, before the deposition of the conglomerate of Mell Fell, all the Upper Silurian strata had been probably planed away over much of the northern part of the district, and a very large proportion of the beds of the Volcanic Series, exposing a great tract of Skiddaw Slates. If this denudation means a removal of some 25,000 ft. or more, of rock, how vast a time does it represent, how slow must have been the elevation of the block of country above the sea, to enable this great agent to effect so much, and how prodigious the sub-aerial denudation wrought upon the elevated land! Of course it is evident that the Mell Fell conglomerate once extended much farther to the west, since the summit of that hill is 1,760 ft. above the sea, this implying another great amount of denudation in later times.

As no fossils—save a few traces of plants—have been found in this deposit, its mode of origin is not a little doubtful, whether

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* In this connexion see an article by the author on "Ice Phenomena in the Lake District," *Nature, Feb. 18th*, 1875.

† SEDGWICK, in 1832, showed "that the mineralogical axis of the whole region may be placed in the direction of a line drawn from the centre of Skiddaw Forest to Egremont" (App. 14). Harkness also concludes that *all* the Silurian rocks in Cumberland and Westmoreland were elevated at the same time, producing a W.S.W. and E.N.E. strike. He also refers to the great denudation which then took place, App. 42.

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accumulated in old valleys as suggested by Prof. Phillips* and Mr. Godwin Austen,† or forming the earliest coast-line beds of the Carboniferous sea. Prof. Ramsay‡ and the Rev. J. G. Cumming§ have suggested that glacial action had something to do with its formation. Certainly some of the stones taken from the Mell Fell conglomerate have the appearance of ice-smoothing and striation. However this may be, it seems certain that those forming the Mell Fell beds, have been brought to their present position from some distance, since they are almost all of grit or micaceous sandstone, which last Mr. Aveline identifies with that of some of the Upper Silurian (Ludlows) of the southern part of the district.‖ I have, in *Mell Fell*, found *no* undoubted instances of pebbles of trap or ash, though some of the small reddened and flaky pieces in the general matrix *may* belong to the Skiddaw Slate. At Hutton, however, two miles to the east, there are numerous pebbles of trap, ash, altered Skiddaw Slate, and limestone (probably Coniston). At Pooley Bridge, where the blocks are sometimes as much as 3 ft. long, sandstone and grit largely predominate, ash or trap being scarce. In most cases the pebbles and large angular blocks lie with their long axes in the direction of the bedding. All this would seem to indicate that, after the removal in the Mell Fell area of a great thickness of the Silurian and volcanic rocks, so as to expose the Skiddaw Slate, facilities were afforded for the northward drifting of materials derived from Upper Silurian strata, while at the same time the neighbouring Volcanic and Skiddaw Slate beds were in part *protected* from denudation. Is it possible that the sandstone pebbles were drifted northwards around the skirts of a tract of high land, which, not rising in any lofty peaks, was effectually protected from marine and sub-aerial denudation, at that particular time, by an icy covering, leaving few or no rocks exposed above its surface? The pebbles of ash and trap in the Hutton deposit seem many of them to belong to the Eycott Hill series, which, lying outside the tract of high ground, may have been more open to denudation. Such a supposition as the above might partly account for the peculiar distribution of the materials forming the conglomerate, though it is evident that the *present* distribution of the formation, as a whole, is mainly due to denudation taking place subsequently, and *possibly* in great measure before the deposition of the first limestone beds beneath the milder Carboniferous sea. Further research may better explain this somewhat difficult problem.

(e.) *Carboniferous Period.*

There is no decided evidence to show that the Carboniferous strata were ever deposited over the whole of the present Lake-

* *Geology of Yorkshire*, vol. ii. p. 14. Murray, London. 1835.
† *Quart. Journ. Geol. Soc.*, vol. xii. p. 53. 1856.
‡ *Quart. Journ. Geol. Soc.* vol. xi. p. 187. 1855. *Reader*, Aug. 12, 1865.
§ *The Isle of Man, its History, &c.*, p. 89. Van Voorst, London. 1848. *Article on Geology in Hist. and Topog. Counties of Cumberland and Westmoreland.* by W. Whellan, p. 28. Pontefract 1860.
‖ At this period these U. Silurian strata may, of course, have stretched much farther north, in some directions.

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district area, but that the limestone beds once extended farther towards the present mountain centre, than they now do, is certain. The thickness of some of the limestones skirting the district perhaps suggests a very considerable further extension, and the area of land during at all events the earlier part of the Carboniferous Period may have been comparatively small, and have attained no great elevation. It is hoped however that further light may be thrown upon this question when the rocks encircling the district have all been carefully mapped.*

(f.) *Post-Carboniferous Times.*

Of the geological history of this district during late Palæozoic, Secondary, and Tertiary times, little can be said, for no records have been left, but their absence and the nature of the district, seem to imply that, during this vast length of time, our present mountain scenery was being slowly elaborated by atmospheric agencies from the rough-hewn block of country left by the sea at the close of the Old Red Period or earlier part of the Carboniferous.

The evidence, found in the district of the last Glacial Period, will be considered in a chapter by itself.

(g.) *Summary of the Chapter.*

The series of events just passed in review may be thus briefly summarized.

The most ancient geologic records in the district indicate marine conditions with a probable proximity of land. Sub-marine volcanoes broke out during the close of this period, followed by an elevation of land, with continued volcanic eruptions, of which perhaps the present site of Keswick was one of the chief centres. Depression of the volcanic district then ensued beneath the sea, with the probable cessation of volcanic activity; much denudation was effected; another slight volcanic outburst accompanied the formation of the Coniston Limestone, and then the old deposits of Skiddaw Slate and volcanic material were buried thousands of feet deep beneath strata formed in an Upper Silurian sea. Next followed an immensely long period of elevation accompanied by disturbance and alteration of the rocks, and by a prodigious amount of marine and atmospheric denudation. A subsequent depression, to a considerable extent, marked the coming on of the Carboniferous epoch, heralded however, in all likelihood, by a period of more or less intense cold. Then for succeeding ages, the district elevated high above the surrounding seas of later times, underwent that large amount of sub-aerial denudation which has resulted in the formation of our beautiful English Lake-country.

* Prof. Sedgwick remarked, in 1836 (App. 16), "Had our island been laid "dry immediately after the Carboniferous period, without any change of relative "position among the great formations, the Cumbrian mountains would have appeared "as a cluster of ancient rocks rising out of a great carboniferous plain."

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CHAPTER XIII.

Glacial Phenomena of the District.*

The points of evidence which clearly prove the former existence of glaciers in this district are, the existence of glacial scratches and ice-worn rocks, of old glacial moraines, of transported and perched blocks, and of clayey drift-deposits due to the grinding action of ice with its stony chisels.

The small arrows on the Sketch-map, Plate IV., show the directions in which the ice-scratches point, and the dots of various colours and patterns indicate the distribution of boulders from the parent rock.

(a.) Direction and Height of the Ice-Scratches.

The several valleys shall be taken in the following order:—

1. Borrowdale.
2. Thirlmere Valley.
3. Keswick Vale, and its smaller side valleys.
4. Buttermere and Lorton Vale.
5. Ennerdale.
6. Head of the Ullswater Valley.

1. *Borrowdale.*

Upper and branching parts of Borrowdale.—At the head of Greenup Gill, upon the watershedding line between it and Wythburn Beck, are scratches running N.W. and S.E. at a height of 2,000 feet. At Long Crag 2,000 feet, quite at the head of the Gill, scratches run N.N.W. and S.S.E., and below the Crag are others with a N. and S. direction pointing straight down the upper part of the valley.

On the eastern side of the Gill there are no scratches in the low parts of the valley, but many well-marked ones on the Fell above, between 1,500 and 2,000 feet, all having a N.N.W. and S.S.E. direction. Thus, there are two instances, just north of Ullscarf (Map, 34),† where the groovings are above 2,000 feet, passing across Coldbarrow Fell; and many scratches point down the upper part of Watendlath Valley between Blea and Watendlath Tarns.

Upon the west side of Greenup Gill they run N.N.W. and S.S.E. over Eagle Crag, to heights of 1,500 to 1,700 feet.

In Longstrath Valley the direction is straight down the stream at the lower levels, but on the east side it is N.N.W. and S.S.E. above the 1,250 line, running across the highest ground, Serjeant's

* *See also* papers by the author, App. 145, 148, 153; and List of Glacial Papers in Appendix.

† The figures in brackets, placed after the names of mountains, refer to small figures showing the positions of the mountains on the sketch-map, and a table of their heights is given on a page following Plate IV.

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Crag, at a height of 1,872 feet. Again, on the west side, below the 1,000 feet contour, the direction is with the valley-side; but upon the fell-top, at heights of 2,000 feet, there are scratches pointing N.N.W. and S.S.E.

Between the point where the Greenup and Longstrath Becks join, and Stonethwaite, the direction is either N.N.W., or N.W. with that of the river.

At the head of the short valley of Comb Gill, below Glaramara (46), the scratches are seen on the east side, at 1,700 feet, near Rosthwaite Cam, striking N.N.W. and S.S.E. directly over the crags into the Comb. Lower down the direction is almost N. and S. with the gill; but upon the east side, below High Knott, where the main valley is gained, the direction suddenly changes to N.N.E. and S.S.W., to N.E. and S.W., and in one case very nearly to E. and W.

In the upper parts of the Derwent Valley, from Sprinkling Tarn to Stockley Bridge, the direction is slightly across the river, *i.e.* N.N.W. and S.S.E., up to a height below Great End of over 2,000 feet, and upon the east side, below Glaramara, of nearly 2,000 feet. Upon the west side of the Derwent, in this its upper course, there are several minor streams and valleys running into the main one. Of these, down the Styhead Gill the general direction of the scratches, from about 1,800 feet downwards, is with the stream, but almost upon the watershedding line, between Sty Head and Great Gable, there are groovings at a height of 2,000 feet, running N.N.E. and S.S.W.

Between Stockley Bridge and Seathwaite, upon the west side of the Derwent, the course is with the valley. West of Seathwaite, Sourmilk Gill joins the Derwent, flowing out of an oval comb lying between Base Brown (45) and Grey Knotts (33); here the scratches, which in the Comb, at 1,500 feet, are N.E. and S.W., change to E.N.E. and W.S.W. at 1,250 feet, where the gill turns due east to fall down the mountain side, in a succession of cascades, into the Derwent.

Between the Plumbago Mine and Seatoller the direction is various. On the wooded hill-slope it is for the most part with the river, N.E. and S.W. On the hill-top at the Plumbago Mine it is N.N.W. and S.S.E. At a point a little farther east, overlooking Buttermere Hause, and over 1,250 feet high, it is N.N.E. and S.S.W.; while down the Dale between the Hause and Seatoller the course is with the stream, E.N.E. and W.S.W.

West side of Main Valley from Seatoller to Portinscale.—Just north of Seatoller the scratches have a N.N.E. and S.S.W. direction, some passing directly over the summit of the wooded hill (927 feet) west of Longthwaite, and others in the pass between it and the higher ground of Scawdel. A short east and west ravine runs up by High Scawdel, and the glacial markings on either side are directly E. and W. On the fell top, at Lobstone Band, the direction is N.E. and S.W. at a height of 1,750 feet. Below, upon Castle Crag, and in the pass between it and Gate Crags, it is N.N.E. and S.S.W., shifting to N.N.W. and S.S.E. from Low Scawdel, by

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Grange, to Cat Bells (15), up the flanks of which mountain some of the scratches run slantingly.

East side of Main Valley from Rosthwaite to Keswick.—Upon Rosthwaite, Watendlath, and Grange Fells, the ice-scratches are very numerous and their direction is uniformly N.N.W. and S.S.E., this being also the trend of the long narrow upland Watendlath Valley which opens above the eastern side of the head of Derwentwater. The scorings upon the moutonnéed ash and breccia rocks of Grange and Brund Fells are among the strongest in the district. It is worthy of notice that from above Watendlath, northwards, few or no scratched surfaces occur above the 1,500 feet contour.

Above Barrow House and beneath Falcon Crag the course is almost directly N. and S., but on the fell-top above the Wallow Crags and close to their edge, the N.N.W. and S.S.E. direction is again very marked at a height of nearly 1,200 feet, as it is also on Castle Head, near Keswick, which is 529 feet above sea-level.

2. *Thirlmere Valley.*

East side of Thirlmere Valley.—Commencing at its upper part, at the Pass of Dunmail Raise, scratches occur on the north side of Raise Beck at 1,500 feet, with a direction of E.S.E. and W.N.W., *i.e.*, with the Beck; and at Riggle Knott on the west flanks of Seat Sandal (the Cumberland Sandal) the direction is N.N.W. and S.S.E. at nearly 1,250 feet. At Birk Side, close to the Helvellyn track, are scratches with the same direction at 2,000 feet, while others lower down by the side of Comb Gill run W.N.W. and E.S.E.

Along the east side of Thirlmere the markings run with the length of the lake. High up on the mountain top, in Browncove, north of Helvellyn (36), there are scratches at 2,500 feet, N.N.W. and S.S.E., and the same general direction is maintained along the mountain side east of the high road. At one place, just north of the E. and W. part of Helvellyn Gill, this direction is crossed by another set of scratches running nearly N.E. and S.W. up the hill.

At a height of 1,500 feet near Sty Beck, the direction is E. and W., though a little lower on the hill-side the northerly scratches are seen.

Still keeping to the east of the stream, now called St. John's Beck, scratches are found in a few places running almost directly N. and S. along the precipitous eastern flank of St. John's Vale, but none are found beyond the mouth of the Vale.

West side of Thirlmere Valley.—Scratches, nearly N. and S., occur at 1,000 feet on the west side of the Ambleside Road, a little north of Dunmail Raise. Just beyond this, the vale down which Wyth Burn flows, joins the main valley.

The scratches upon the water-shed at the head of this valley, at a height of 2,000 feet, have already been alluded to when speaking of Greenup Gill on the other side. Others at the same height are found at Green Comb (S. of Ullscarf), running S.E. and N.W.

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Lower down the direction agrees with that of the stream, E.N.E. at first, changing to N.E. and N.N.E. below Steel Fell (47).

On the hill-flanks from Wythburn, along the west side of Thirlmere, there is one set of scratches directly following the valley. This is crossed by another set, around Harrop Tarn, having an E.N.E. direction, the scratches pointing out of the open Comb in which the Tarn lies and over the cliffs by Dob Gill. A third direction is taken by the scratches across Wythburn and Armboth Fells, which point N.N.W. and S.S.E. *quite across* the water-shed, to a height of 1,750 feet; the groovings being most numerous a little north of Blea Tarn (head of Watendlath Beck), where all the ground above 1,500 feet forms the narrowest ridge.

The lower end of the Thirlmere valley is divided into two by a long ridge, commencing near Thirlspot and running north as far as Tewet Tarn, a little south of the Keswick and Penrith road. This ridge is completely broken through at High Bridgend, where the river, flowing out of the lake, turns at right angles and passes directly from one valley into another, pursuing the rest of its course down the St. John's Vale. To the north of this break the parting ridge attains a height of 1,000 feet, but one end of it, called High Rigg (18), is separated from a lower part farther north called Low Rigg, by the pass in which St. John's church stands. The scratches have a general N N.W. and S.S.E. direction over High Rigg, but beyond this none are seen.

The valley to the west of High Rigg is called the Naddle Valley, and the narrow Shoulthwaite Vale opens into it just north-west of Shoulthwaite Moss; some scratches partly cross the mouth of this last vale in an E.N.E. and W.S.W. direction, others cross it from N.N.W. to S.S.E. A like direction (N.N.W.) is observed in scratches upon the summit of Castlerigg Fell from 1,500 feet downwards.

3. *Keswick Vale, and its smaller Side Valleys.*

There are but few spots where scratches are seen in this open vale, and they are all in the narrow part of it, near the head of Bassenthwaite Lake. This scarcity is in part due to the covering of drift, and in part to the splintery character of the Skiddaw slates. It should be noticed that almost all the scratches hitherto described are upon rocks of the volcanic series.

North side of Keswick Vale.—Upon the southern flanks of Blencathra (2), at 700 feet, are scratches running parallel with the mountain-side.

Upon the lower flanks of Skiddaw (1), above Lyzwick Hall, the slate is well smoothed and scratched at a height of 800 feet, the scratches running N.W. and S.E. Low down upon the north-western flanks of the Dodd the slate is well rounded, but the surfaces are rough. Upon a surface of intrusive diorite, on the north side of Bassenthwaite Lake, close to Bowness Wood, are scratches with a direction but very little W. of N. and E. of S.

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South side of Keswick Vale.—Just south of Barf (7) are scratches with a N.W. and S.E. direction at 600 feet; and a little south of Wythop Hall others occur upon a surface of intrusive trap at a height of between 700 and 800 feet with an E.N.E. and W.S.W. direction.

Side valleys joining Keswick Vale, other than the Borrowdale and Thirlmere Valleys.—The Newland's Vale joins the main valley between Braithwaite and Portinscale. The Newland's Beck rises east of Dale Head (31) and flows down a straight, wide, but craggy-sided valley, as far as Newland's Church, where side streams join it. Throughout this upper part the direction of the scratches is that of the valley, and they occur to a height of 1,250 ft. Close to Little Town the direction is N.N.E. and S.S.W. Near this spot Scope Beck joins the main stream; it flows from Little Dale, between Robinson (29) and Hindscarth (30), and in this Dale are scratches running N.N.E. and S.S.W. at 1,420 ft., and others more nearly N.E. and S.W. lower down.

Keskadale Beck is another joining the main one near Little Town; it flows down the wide valley from Newland's Hause, and at its head are the Robinson Crags; beneath these occur many scratched surfaces, the direction in some cases being E. and W., in others N.N.W. and S.S.E., and their height from 1,000 to nearly 1,500 ft. Others are found, across the stream, by the road side just east of the Hause—which is 1,095 ft.—at a height of 950 ft., and having two directions, one N.E. and S.W. with the valley; the other N.N.E. and S.S.W., up the hill-side. Much farther down and along the line of the main valley scratched surfaces occur west of Stair, and upon Barrow at 1,400 ft.; also at the north end of Barrow, above Little Braithwaite, the grooves, all course nearly north and south.

4. *Buttermere and Lorton Valley.*

East side of Buttermere and Lorton Valley.—On the north side of Gatesgarthdale Beck, which flows down from Honister Pass, the scratches run with the direction of the valley. But high above the level of the Pass, and a little south of Dale Head (31), there are others with an E. and W. direction at 2,200 ft.

Lower down the valley, as far as Buttermere village, the direction is the same as that of the stream and lake, but they are not found at a greater height than 700 ft. South, however, of the road from Newland's Hause to Buttermere there are scratches to a height of 1,500 ft. Just west of the Hause, by the road side, at 1,000 ft. are some with an E. and W. direction, crossed by others running N.W. and S.E. A little north of High Snockrigg, where they are found at 1,500 ft., the direction is S.W. and N.E., changing lower down to nearly N.W. and S.E. at 620 ft., *i.e.* about the direction of the main valley.

Along the flanks of Rannerdale Knotts, the scratches run with the hill-side and valley, and there are some at 800 ft. pointing down the small valley separating these Knotts from Whiteless

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Pike (28), while along the western flanks of Grasmoor (11) they are found up to a height of over 1,000 ft. taking the general direction of the valley.

On the western flanks of Whiteside (10) and near Scalehill Hotel, there are scratches up to 600 ft. pointing down the Lorton Valley, but none further north than this have been observed.

Scratches also occur beneath Hobcarton Crags at 1,800 ft. pointing N. and S.

West side of Buttermere and Lorton Valley.—Just on the south side of Honister Pass (west of the watershed) there are scratches up to 1,500 ft., with a nearly N. and S. direction. A little lower, beneath Honister Crag, the direction is that of the valley and changes with its curving.

On the summit and back of Honister Crag there are many scratched surfaces and moutonnéed rocks to a height of 1,750 ft., the general direction being N.W. and S.E., and passing directly over the crags which form the head of Warnscale Bottom. Just north of Scarf Gap the direction, at 1,250 ft., is N. and S., changing lower down, at 800 and 900 ft., into N.W. and S.E., which is the direction of the main valley. These N.W. and S.E. markings are found all along the south-west side of Buttermere Lake, but nowhere above 800 ft.

Overlooking Buttermere, upon this same side, are three Combs formed by the heights of High Crag (27), High Stile (26), and Red Pike (25). Burtness Comb lies between High Crag, 2,442 ft., and High Stile, 2,643 ft.; there are scratches at a height of 1,750 ft. pointing straight down the Comb in a N.E. direction. In the next, between High Stile and Red Pike, 2,478 ft., there are no scratches to be seen, but the rocks are rounded as if by an agent working directly out of it; and the same may be said of Ling Comb directly north of Red Pike.

Immediately west of Scale Force scratches occur at 1,000 ft. pointing N.W. and S.E., and a little below, at 800 ft., the direction is E. and W. Farther on, north-west of Gale Fell, the direction at 1,400 and 1,000 ft., is N. and S., directly down the hill-side, and again on the south bank of Floutern Tarn, at 1,250 ft., it is the same.

Down Mosedale, which runs due north and south from Gale Fell, scratches occur, crossing the vale from S.E. to N.W. near its upper end, and lower down near its mouth, running in a N.N.W. and N.W. direction. All along the west side of Crummock Water the groovings run parallel with the lake and occur on the flanks of Mellbreak (22) up to 700 ft.; but, at the lower end of Crummock Water, the direction becomes N.W. and S.E. Farther down the valley, N. and S. scratches occur close to Redhow, near the river, at 400 ft., but none more northward than this, though well rounded rocks may be seen at Rogerscale, a mile north-west of Low Lorton.

Loweswater drains into Crummock Water, with a fall of 100 ft. in 1½ miles; scratches run W.N.W. and E.S.E. on both sides of

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the lake up to a height of 700 ft., and occur at 900 ft. with a N. and S. course, in the valley just east of Carling Knott (9).

5. *Ennerdale Valley.*

This is a long straight valley running E.N.E. from Great Gable, bounded north and south by lofty mountain ranges, and having Ennerdale Water at its mouth, where it opens out into the low country.

North side of Ennerdale Valley.—The river Liza rises on the northern slopes of Great Gable and flows into the head of Ennerdale Lake. On its north side scratches are seen in the valley-bottom amongst the moraines at a height of 1,000 ft., a little east of where the Scarf Gap and Black Sail path crosses the stream. Between this spot and the Lake the slopes on the north side of the valley are covered with screes to an average height of 1,250 ft., and no scratched surfaces are exposed.

Close to the head of the lake, by the road-side, there are striations running nearly N.W. and S.E., while, on the summit of Latter Barrow, 900 ft., the rocks seem to have been ice-rounded from the east, as also on the southern flanks of Great Borne (23) at a height of 1,250 ft.

Half way down the lake, where it is pinched in by Bowness Knoll on the north and Angler's Crag on the south, there are well scratched surfaces close to the water's edge, the direction being N.W. and S.E. West of this the valley opens out into the low country.

South side of Ennerdale Valley.—On the south side of the Liza scratches are first seen on the northern slope of Kirk Fell (43), up to a height of 2,000 ft. At this height the direction is N.N.E. and S.S.W. At 1,500 ft. and 1,250 ft., just east of the Black Sail path, it is N. and S.; and at about 1,400 ft., on the west side of the path, it is N.N.W. and S.S.E.

In the valley-bottom below the Pillar (42), there are scratches pointing straight down the valley at between 800 and 900 ft.

Along the Pillar range, overlooking Ennerdale, is a series of Coves or Combs, above which rise the Pillar (42), 2,926 ft., Little Scoatfell, 2,760 ft., and Haycock (41) 2,619 ft. In Pillar Cove there are scratches, from 2,250 ft. to 1,500 ft., pointing straight down the mountain side. In Windgap Cove, between Pillar and Steeple, there are also many others between about 2,200 ft. and 1,500 ft., with a general N. and S. direction, coming straight out of the Comb. Immediately west of this is Mirklin Cove, with scratches at a little over 2,000 ft. running in a N.N.W. and S.S.E. direction. Just north of Haycock (41) and west of the last, is Great Cove, having striations pointing directly out of it at a little above 1,750 ft. in a N.W. direction, while others, with the same direction, occur low down at 550 ft., where Deep Gill joins Silvercove Beck. Also along the course of this last Beck there are N. and S. scratches at a little over 1,000 ft. So that there are groovings pointing directly out of every cove along these southern flanks

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of the Ennerdale Valley, up to a height in several cases of considerably more than 2,000 ft.

6. *Head of the Ullswater Valley.*

Several wide and deep dales run eastwards or north-eastwards from the lofty Helvellyn range and join the Ullswater Valley and Patterdale. The northernmost is Deep Dale (Cumberland Deep Dale), down which Airey Beck takes its course, and in which glacial striations are not very numerous; they occur, however, above Dowthwaitehead at a height of rather more than 1,250 feet, pointing N.E., and about Dockray and Thornythwaite, at heights of about 1,000 feet, some with a direction pointing N.E. or E.N.E. out of the valley, and others nearly due N. and S.

Glencoin Dale joins Ullswater at the angle of the first bend, and scratches occur at its head from a height of 1,900 feet downwards, pointing down the valley. At the west corner of Glencoin Wood (S. side of valley), there are others having a N.E. and S.W. course, at a height of 1,300 feet.

A mile further south is the Glenridding Valley; its head divides on either side of Catstye Cam, each branch ending in fine combs beneath Helvellyn (36). On the north side, in both Keppel and Brown Coves, there are scratches pointing out of them from heights of fully 2,500 feet downwards; and in the Red Tarn Cove there are some, close to the upper end of the Tarn, at a little below 2,500 feet. Upon the southern side of Glenridding, beneath Nab Crag, and on the ridge parting this valley from Grisedale, are several instances at heights of from 1,750 feet, downwards, with an E.N.E. or N.E. direction.

Grisedale is a wide valley opening out at the head of Ullswater and running up to Grisedale Tarn, with several branches on the north side ending in fine coves (Nethermost, Ruthwaite, and Cock Coves) beneath and south of Helvellyn. In each of these Coves scratches occur, pointing outwards, at varying heights from above 2,000 feet, and on either side of the main valley at heights of from 1,750 feet downwards. Deep Dale (Westmoreland) is another large valley, a little farther south, running into the upper part of Patterdale. At its head are two fine rocky coves (Link and Cawk Coves), out of which glacial scratches point, at heights ranging from 2,000 feet downwards. Upon the north and south sides of the main valley they take a decided transverse direction, crossing the lower part of the Gavel Pike (38) ridge at 1,750 feet, and the ridge on the south, parting Deep Dale from Hartsop Dale, at heights of 1,600 feet.

Hartsop Dale, running up south-westwards from Brothers Water, likewise shows numerous glacial striations in its picturesque, rocky, wooded coves, and pointing out of the coves at heights up to 2,000 feet, though in the lower part of the valley the direction is partly across the ridge on the north, as just mentioned.

Along the course of Patterdale itself the cases are very numerous, and upon either side of the upper reach of Ullswater.

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From the end of Deep Dale (Westmoreland) the direction is very markedly to the N.W., over the summit of Annstone Crag (1,423 feet).

(b.) Moraines, Old Lakes, and Boulders.*

1. *Borrowdale.*

Moraines and Old Lakes. — Commencing with the higher branches on the east, we find the Greenup Valley literally choked with large moraines, much cut up by stream-courses, between the 1,000 and 1,500 contours. In the wider Long Strath valley they are found in the higher parts, from 600 feet upwards, forming well-marked, parallel mounds, running N. and S. just below the junction of Stake Beck with Long Strath Beck, and a great succession of irregular mounds higher up on either side of this latter stream, some occurring at the foot of Angle Tarn at a height of 1,750 feet. Following up Stake Beck an immense number of irregular moraine-like mounds begin to come on at about 1,500 feet, and continue quite over the summit of the Stake Pass, 1,575 feet, and down the other side for an equal distance.

In the Comb, between Thornythwaite and Rosthwaite Fells, is a small group of moraines surrounding a filled-up tarn, at 1,000 feet.

At the head of the river Derwent, where several streams join, S.E. of Senthwaite Fell, are several large moraines, at between 1,000 and 1,250 feet, some fine sections of which are exposed. Just below the junction of Styhead Gill with the Derwent, a great number occur on the east bank of the river, running for the most part parallel with it, at heights of from 450 to 600 feet.

At the mouth of Sourmilk Comb (W. of Seathwaite), irregular mounds of moraine material occur between 1,250 and 1,500 feet, beyond the end of a filled-up tarn. Between Seathwaite and Seatoller is the site of a former lake 1½ miles long, but near its end, a moraine nearly stretches across the valley from its eastern side to Thornythwaite, a higher terrace of river gravel occurring directly behind (or N.E. of) it.

In Little Gatesgarth Dale are many moraine mounds from 800 feet to the summit of Ho[illegible]ster Pass, 1,190 feet; but on the north side of the Dale these mounds are blended with modern stream-course mounds or *dry deltas.*

Just W. of Rosthwaite church are several long narrow moraines stretching across the end of the Seathwaite Valley, and having large boulders upon them; this is at a height of 320 feet.

The alluvial tract running up the Stonethwaite Valley probably marks the site of another old lake, or possibly—at one time—of merely an arm of the Seathwaite lake; while below Rosthwaite a similar tract of an oval form shows the former presence of a lake rather larger than Grasmere as it now exists. At the foot of the

* See map, Plate IV., for boulder distribution.

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old Rosthwaite Lake, by the road side, is what are probably the remains of an old moraine, which may have helped to dam the waters back.

A stretch of low lands, often now flooded—for the waters of the Derwent during great floods sometimes sweep quite over Grange Bridge—marks the former higher extension of Derwent Water, and for three-quarters of a mile from the mouth of the Derwent a long stretch of shallow water extends, the depth ranging from only 5 to 18 feet, with a deep channel on either side, that on the E. being the deepest, with a maximum of 72 feet.

Several small peat-mosses on Grange and Watendlath Fells mark the site of old tarns, and at one end of Dock Tarn this process of filling up is well seen now going on. One large oval peat between Blea and Watendlath Tarns represents a sheet of water equal in size to the former, and Watendlath Tarn itself must once have been twice its present size. Just above it there is much moraine-like matter upon rounded bosses of rock; and on the hill-top above the village, in the deep ravine of Raise Beck, is the remains of a moraine which seems formerly to have stretched across the gully, but has since been cut through by the stream.

Transported and perched blocks.—Taking first the eastern boundary of the valley under consideration, viz., the watershedding line running from High White Stones through Ullscarf (34) to High Seat and Castlerigg Fell, we find boulders which have evidently been transported a greater or less distance at the following points *along that line.* Perched blocks on Greenup Edge somewhat over 2,000 feet. A great number of large boulders just east of Blea Tarn at 1,730 feet. Perched block just north of Blea Tarn at 1,660 feet, and another a little farther north, at Shivery Knott, 1,600 feet Boulders at about 1,660 feet, just S. of the track between Watendlath and Thirlmere. All the above-mentioned are blocks of the Volcanic Series, and rest upon similar rocks.

Over the Fells between this watershedding line and the valley bottom on the west there are many similar cases, a few of which may be mentioned. Many large perched blocks below Blea Tarn and between it and Watendlath. Some on Green Comb, 1,580 feet, just S.E. of Dock Tarn, and many more around at lower elevations. On the fell-tops on either side of the Watendlath Vale; one large one in particular on Ashness Fell, west of High Seat, at about 1,650 feet; others along the hill side, above Barrow, to Wallow Crag (16); at the south end of these crags are fragments of the Armboth quartz felsite dyke, and some small boulders of the same occur on the south flanks of Bleaberry Fell (17), at a height of fully 1,800 feet.

Returning to the head of Borrowdale, we find many moraines on the summit of the Stake Pass, 1,600 feet, between Longstrath and Langdale. Along the ridge separating Greenup from Longstrath are perched blocks at a height of 1,800 feet on Sergeant's Crag, and over 1,500 feet on Eagle Crag. On the Fells between Longstrath and Seathwaite Vale there are perched blocks on Glaramara, at 2,000 feet (Fig. 4, Plate VI.), and some fine ones farther

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north, close to Tarn-at-Leaves, at nearly 1,750 feet. Between Styhead Gill and the Derwent, they are found north of Sprinkling Tarn from 2,000 feet downwards; and upon the water-shedding line between Great Gable and Honister Pass, on Grey Knotts (33), at a height of 2,280 feet.

In all the lower parts of Borrowdale perched blocks are numerous enough. Once beyond Grange, along the west side of Derwentwater, the mountains are composed of Skiddaw Slate, and the detection of travelled blocks becomes easier.

Maiden Moor, a little to the north-west of Grange and a full half-mile north of the nearest rocks of the Volcanic Series, has a height of 1,887 feet, and there are ash and trap boulders upon the top; these may be traced at intervals all along the ridge to the extremity of Cat Bells (15). At one spot, however, called Hause Gate,—the lowest between Maiden Moor and Cat Bells—the boulders are in particular abundance, and may be traced at intervals up the hill-side from the low ground at the head of the lake. Swinside, a rounded hill 800 feet high to the north of Cat Bells, has perched blocks from Borrowdale upon it up to its summit. The further northward tracking of rocks transported from Borrowdale will be left until we consider Keswick Vale and its boulders.

2. *Thirlmere Valley.*

Moraines and old lakes.—There are many moraine mounds on either side of Wyth Burn, in its upper part (Fig. 5, Plate VI.), from 1,600 feet to 1,250 feet, with three filled-up tarns, one of which, called the Bog, is nearly half a mile in length.

On either side of the Pass of Dunmail Raise, moraines are frequent; one is specially well preserved, running N.E. and S.W. a little south of Steel End. Moraine-like material also occurs on either side of Raise Beck, at 1,225 feet. No very marked moraines occur along the east side of the Thirlmere Valley, though here and there are apparently the remains of some, as by Comb Gill, west of Birk Side (Helvellyn), on the south side of Sty Beck, at 1,250 feet, and, perhaps in Stanah Gill, west of Stybarrow Dodd (21) at 1,750 feet; and below Wanthwaite Crags, at the north end of St. John's Vale, where old moraine mounds are probably mingled with modern stream detritus at a height of 1,000 feet. On the west side of the valley, a little moraine matter may be noticed resting upon and against the ice-worn rocks at the foot of Harrop Tarn, which must formerly have been at least three times its present size. There are also some moraines with very large blocks in connection with them at the end of Shoulthwaite Gill.

Thirlmere must formerly have been a mile and a quarter longer than at present, and each arm of the double valley at the northern end of Thirlmere once contained its lake or lakes. The stretch of alluvial land in St. John's Vale is even now sometimes completely under water, and the lake seems formerly to have been dammed back by a long mound of sand and gravel now cut through

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by the stream, to which allusion will shortly be made.* In the Naddle Valley, Shoulthwaite Moss was clearly a small lake into which the scree material from the Benn must have slipped, as such material now does into Wastwater. This old lake must have been joined by a narrow neck with a longer and larger lake in the hollow west of High (18) and Low Rigg, which, like its fellow in St. John's Vale, seems to have been dammed by a mound of sand and gravel, a little south of Naddle Bridge, now cut through by the Beck.

Transported and perched blocks.—First, those of the eastern side of the valley shall be noticed. A little S.W. of Dollywaggon Pike (37), at about 2,200 feet, a boulder of compact blue trap lies upon the hill flank, which is wholly composed of coarse ash or breccia; others occur at lower levels.

The rocks of the Browncove Crags consist of coarse ash and breccia altered in parts into a very close felstone-looking rock by numerous dykes. The scratches in Browncove, at 2,500 feet, have already been noticed; but, in addition to such ice-markings, scratched stones occur at the head of the gill a very little below 2,500 feet, and a great stream of huge ash boulders may be traced from the crags down and across the mountain side in a N.N.W. direction (agreeing with that of the scratches) towards Thirlspot.

Blocks, apparently transported, occur west of the watershedding line, a little south of Raise (35), at 2,700 feet, and again up to 2,500 feet near where the miner's path crosses the line, north of the Raise. Boulders occur in Stanah Gill, west of Stybarrow Dodd (21), up to 1,600 feet.

A boulder of the Armboth and Helvellyn dyke is found above Thirlspot, at a height of 1,000 feet. On the west side of the valley there are perched blocks on the top of the crags a quarter of a mile south-west of Harrop Tarn, at a height of over 1,750 feet, and they are found at intervals, on the east of, and up to the watershedding line, all across the Wythburn and Armboth Fells. Between High Seat and the upper part of Shoulthwaite Gill there are a great many scattered boulders on the slope, up to a height of 1,750 feet. Boulders of the Armboth and Helvellyn dyke are found in the Shoulthwaite and Naddle Valleys, the most western point, where the dyke is seen, being on the fell-top quite at the head of the Shoulthwaite Gill. Perched blocks also occur all over High Rigg (18), and one of the dyke just mentioned occurs perched at a height of 800 feet on the north end of High Rigg, a little south-west of St. John's Church.

3. *Keswick Vale.*

(Including under this head all the open and non-mountainous ground between Mell Fell on the east and Bassenthwaite Lake on the west.)

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* In St. John's Vale, in superficial deposits, have been found stones with circular perforations, evidently artificial, and which may have been used as fishing weights (or spindle-whorls) by a past race, perhaps the same people who made the stone celts found in the immediate neighbourhood (see p. 100).

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Moraines and old lakes.—There are no true undoubted moraines in the valley, though some of the Drift deposits, presently to be noticed, often have the external moundy appearance of such. On the southern margin of Matterdale Common however, just off the edge of the valley now under examination, is a well-marked moraine, below Wolf Crags, at a height of 1,350 ft.

Derwentwater and Bassenthwaite were certainly once united, as now they sometimes are during heavy floods. Wythop Moss, west of Bassenthwaite, and 900 ft. high, is clearly an old upland lake now filled by peat and hill-side wash.

Transported and perched blocks. — These are exceedingly numerous throughout the vale. First, I may mention a great number of huge blocks of ash and trap lying along the hill slope just south of Matterdale Common, on a line with, and east of, the moraine just noticed, and to a height of over 1,500 ft.; one of these measures 18 feet × 9 feet × 9 feet. From this spot, northwards to Troutbeck, the ground is covered with boulders, many of them of huge size, and a very large proportion consisting of the quartz felsite found on either side the N. end of St. John's Vale; they are found also to a height of above 1,250 ft. on Mell Fell (3) and Little Mell Fell.

Passing westwards, boulders are found up to 800 and 900 ft. on the southern slopes of Blencathra (2). More than 100 boulders have been examined in *one* field close to Riddings—W. of Threlkeld, but N. of the Greta—all of these were of ash or trap, with the exception of one of the Armboth dyke and one of spotted schist. A little farther to the west, however, at the end of the Glenderaterra Valley—between Skiddaw and Blencathra—there are a great many boulders of spotted schist and some few of granite mingled with those of ash and trap. Both granite (Skiddaw) and the schist occur about two miles up the Glenderaterra Valley. A small tract of ground just on the *south* side of the Greta, thickly strewn with boulders, was examined; all the blocks were found to be ash or trap, with the exception of one of the Armboth dyke and some few of the St. John's quartz felsite. Over the drift-covered tract, between the N. end of Castlerigg Fell and the foot of Latrigg, there are scattered innumerable boulders, mostly of ash and trap, but a good many both of the Armboth dyke and the St. John's felsite.

Upon the summit of Latrigg (1,200 ft.) there are many blocks of ash and trap, a few of the St. John's quartz felsite, several of the Armboth dyke, a good sprinkling of spotted schist, and one of the Skiddaw granite. On the southern slope of Lonscale Fell blocks of the schist also occur up to 1,250 ft., and ash boulders nearly to that height. Nowhere in the valley of the Glenderaterra, north of its mouth, have I detected any boulders of the Volcanic Series, but one example of an ash boulder occurs on the *north* of the watershed between this valley and that of the Caldew, at a height of 1,300 ft., near the junction of Salehow Beck with the river Caldew (in 101 N.E.)

West of Latrigg, along the southern slopes of Skiddaw, no

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boulders are found at higher elevations than 800 ft., until Lyzwick Wood is reached, where a large group of ash and trap blocks with some of spotted schist and of the Armboth dyke occur, ranging up to heights of 1,250 ft. on the S.E. flanks of Dodd. Just behind Lyzwick Hall, between the 500 and 600 ft. contours, are two immense boulders, one of conglomeratic ash, measuring 18 feet × 14 feet × 8 feet, and the other of altered breccia 17 feet × 12 feet × 9 feet.

Upon the western side of the Derwent the distribution of the boulders is very striking. It has already been mentioned that ash and trap boulders occur along Cat Bells and over Swinside, thence they may be traced in great numbers up to 900 ft. on the N. end of Barrow (just S. of Braithwaite), running up the Coledale Beck to a height of 700 ft., on the sides of Hospital Plantation to 1,250 ft., across the Whinlatter Road, up through Comb Plantation to Whinlatter Knotts, 1,610 ft., and down the other side along the course of the Aiken Beck towards the Lorton Valley. Further north also they may be traced on to Lord's Seat (6) and Broom Fell (4) to an extreme height of 1,670 ft., and onwards across the upland Wythop Vale to Embleton and the lowlands. Indeed, of the mountain tract immediately north of the Whinlatter road (between Lorton and Braithwaite), every part is covered more or less with boulders, except quite the summit of Lord's Seat (1,810 ft.) and Barf (1,535 ft.). Although, however, boulders are so numerous over these mountains, yet, with an exception presently to be noticed, they are all of ash, trap, or diorite; and over some small areas of ground which have been closely examined, and where the blocks lay almost as thickly as possible, not one boulder of St. John's quartz felsite, of the Armboth dyke, of spotted schist, or of granite, has been found. Of course the number of boulders thus examined must necessarily bear a small proportion to the number actually strewn over the whole surface, and blocks of the above-mentioned rocks may yet be found, nevertheless their *absence* is as conspicuous here as their *presence* was on the north side and in the eastern parts of the valley.

The exception just now mentioned is this. Upon Sale Fell, 1,170 ft., on the N. side of the Wythop Vale, occurs the very small patch of minette already described; boulders of it are found on the *south* side of the Wythop Vale, upon the N. side of Kirk Fell to a height of nearly 1,250 ft., and upon the S. side of the watershed uniting Kirk and Broom Fells up to a height of *fully* 1,250 ft., but I have not observed any such blocks farther south or anywhere to the *north* of Sale Fell itself.

Newlands Valley.—A word must be said about the moraines and transported blocks of this tributary valley.

Moraines.—One instance alone occurs, and that is a moraine just in the hollow beneath Robinson Crags upon the east side of Newlands Hause, at a height of from 900 to 1,000 ft.

Transported blocks.—Boulders of ash and trap occur plentifully along the course of Keskadale Beck nearly as high as 700 ft. In the lower parts of Little Dale and the Goldscope Valley there

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occur numerous boulders of diorite similar in character to the intrusive masses upon Hindscarth (30), which mountain lies between the two valleys.

4. *Buttermere and Lorton Valley.*

Moraines and old lakes.—A great deal of irregularly arranged moraine material lies behind Honister Crag, upon Fleetwith (32), between 1,500 and 1,750 ft. high, and above the sites of two old tarns.

No moraines lie in the low ground along the course of the valley, but on the S. side of Buttermere they occur, in Burtness Comb (between High Crag, 27, and High Stile, 26), at between 1,250 and 1,500 ft.; round Bleaberry Tarn (between High Stile and Red Pike, 25) at 1,600 ft., and in Lingcomb (just west of Red Pike) at about 1,500 ft.

Of lakes, filled up in whole or in part, mention may be made of Buttermere, which originally extended into Warnscale Bottom on the south, and was continuous with Crummock on the north; and of Lorton Lake, now completely filled up, but which must at one time have been two miles in length.

Transported and perched blocks.—Upon the eastern side of this valley the Skiddaw Slate alone occurs; at the head and south-western part as far as Red Pike, the Volcanic Series caps the hill side; and south of Buttermere village and the upper end of Crummock Water there occurs a large spread of syenitic granite.

Boulders of ash and trap are found down the whole length of the valley. Upon the eastern side, below the head of Buttermere, they are not found above 800 ft.; some occur at this height up the valley on the W. side of Newland's Hause, one of which measures 6 feet × 4½ feet × 3 feet. Farther down the main valley however, below the head of Crummock Water, boulders of syenitic granite are largely mingled with those of ash and trap, and in some cases they are found some little way up the tributary valleys on the east side, as for instance up Hope Gill on the N.E. side of Dodd, where they occur to over 900 ft., and up the valley to the east of High Lorton as far as Scaw Gill on the Whinlatter road, to between 800 and 900 ft. Upon the southern flanks of Kirk Fell (5)—not the Wastdale mountain of that name—there is one syenitic boulder at 1,100 ft., but such boulders are more rare N. of High Lorton, upon the eastern side of the Cocker, than on the western side, next to be noticed.

Upon the W. side of the valley there are some remarkably fine perched blocks near Blackbeck Tarn (above Warnscale Bottom) at 1,750 ft.; and N. of the syenitic mass boulders of ash, trap, and syenite occur everywhere up to considerable heights. Thus, there are upon Mellbreak (22), a few syenitic boulders, and some of the Volcanic Series, above 1,500 ft. On the northern slopes of Hen Comb and Gavel Fell are others up to 1,250 ft., and upon Burnbank Fell, above and south of Loweswater, is one syenitic boulder at 1,400 ft. Upon Fellbarrow (8), 1,363 ft.,

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many ash, trap, and syenitic blocks may be seen. Still farther north, about Cockermouth, the syenitic granite is still conspicuous among the boulders of ash and trap.

Another point deserving of notice is that on Starling Dodd (24), scarcely more than a mile direct W. from Red Pike (25), there are syenitic boulders to the top, the Dodd itself being altered Skiddaw Slate almost surrounded by syenitic granite *at a lower level*, except quite near the summit of Red Pike.*

5. *Ennerdale Valley.*

Moraines.—Perhaps the most complete series of moraines to be found in the district occurs in the upper part of this valley, immediately below Black Sail, for rather more than a mile along the river Liza, and between 1,250 and 800 ft. Other moraines are found at the mouth of Mirklin Cove (a little east of Haycock) from 1,750 to 1,250 ft., along part of the course of Silvercove Beck, and beneath Caw Fell Crags. A shallow line crossing the lower end of Ennerdale Water probably indicates an old moraine, of which the island is the highest point; its course may be well seen from the summit of Angler's Crag. In other parts of the valley are remains of old moraines.

Transported boulders.—From the centre of Ennerdale Water, syenitic granite forms the hill sides for full three miles up the valley; higher than this the mountains are formed of rocks of the volcanic series. Blocks of this last are found upon the syenitic granite, but syenitic boulders—excepting blocks belonging to some of the dykes of Kirk Fell—are not found upon the Volcanic Series.

6. *Head of the Ullswater Valley.*

Moraines and old lakes.—These occur at the following spots in the various valleys draining eastwards into Patterdale and Ullswater.

Some imperfect mounds in Deepdale, a mile west of Dowthwaitehead; here also and at Dowthwaitehead two old lake-sites occur, each about half a mile long, while at Thornythwaite and Matterdale End there are small filled-up tarns. Moraine mounds are scattered plentifully round the site of an old lake above the Greenside Mine, now used from time to time as a reservoir. A fine moraine, now somewhat injured by embankments for mining purposes, bounds the east side of Keppelcove Tarn, and others occur below a small filled-up tarn in Brown Cove, and round the lower end of Red Tarn.

Round the upper end of the narow alluvial flat in Grisedale are a good many moraine mounds, much cut up by streams; and at the foot of Cawk Cove and the head of Deep Dale (West-

* Since I brought forward this case (Quart. Jour. Geo. Soc., Vol. 29, p. 437) as one of the facts pointing to a probable submergence to a considerable depth beneath the sea, I have found that Prof. Sedgwick in 1825 (App. 94) noticed these same boulders, and from this and allied facts inferred a submergence to the amount of over 2,000 ft.

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moreland) they are very numerous, in the latter case encircling the sites of two small tarns. In Hartsop Dale there are also some moraines, south of Hartsop Hall, and partly bounding a former extension southwards of Brothers Water.

Transported and perched blocks.—On High Brow, just north of Dowthwaitehead (1,800 ft.), are large boulders evidently transported *some* distance, though perhaps not very far. Upon Common Fell (1,810 ft.), above Glencoin Park, there are also large boulders of coarse ash resting upon the edges of cleaved purplish ash. Boulders occur quite up to the summit of Birks (2,039 ft.) on the south side of Grisedale.

Perched blocks may be frequently seen at very great elevations, above 2,000 ft., and are numerous at all lesser heights; but, as in this part of the district the rocks are very uniform in character, it is often impossible to be sure that boulders have been transported any considerable distance.

(c.) Drift Deposits.

There are three kinds or classes of deposit connected with the glacial period in this district, viz.,—1. Till; 2. Drift-gravel; 3. Stratified sand and gravel.

1. *Till.*—Under this head are included patches or spreads of stiff clay stuck full of smoothed and scratched stones and boulders, and unstratified. It occurs every here and there in small patches among the mountains, in rock-sheltered spots, and may frequently be seen in the valleys either by itself or underlying the Drift-gravel, No. 2. In some few places the clay is free from stones and boulders, and is then used for brick, tile, or drain-pipe making.

2. *Drift-gravel.*—This consists of subangular gravel—sometimes containing bands of sand—in a clayey matrix, with large boulders in and upon it. It often passes down into the Till, and either forms sloping plateaux running up the valleys, or wide spreads with a more or less moundy appearance. It occurs largely in Keswick Vale overlying Till, and may be traced in parts of the district to heights of *at least* 1,500 to 1,600 ft.

The following sections from borings along the line of the Cockermouth, Keswick, and Penrith Railway* will illustrate the nature and thickness of these deposits.

	ft.	in.
(1.) Just east of Skiddaw Lodge, Keswick:		
Sandy clay mixed with gravel	5	0
Clay and stones	11	0
Blue clay	7	0
	23	0
(2.) West side of Tunnel, Brigham Forge, Keswick:		
Soil	0	6
Stiff clay and stones	19	6
Blue clay and stones	7	0
	27	0

* Kindly furnished me by the engineer, J. Wood, Esq., C.E.

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(3.) On the site of the Tunnel:

	ft.	in.
Soil	0	6
Stiff clay and stones	11	0
Sand	1	0
Stiff clay and stones	16	0
Rock	—	
	28	6

(4.) Below Brundholme Wood:

Clay and large boulders	5	0
Gravel	15	6
Clay and stones	10	0
Rock	—	
	30	6

(5.) Just east of Mosedale Viaduct (between Threlkeld and Troutbeck):

Clay and stones	7	0
Stiff blue clay	10	0
	17	0

(6.) Three quarters of a mile east of last:

Moss	2	0
Clay and stones	10	6
Sand	1	6
	14	0

(7.) Troutbeck Station:

Clay	3	0
Tough clay	10	6
	13	6

(8.) One mile and a quarter east of Troutbeck:

Stiff clay and stones	9	0
Clay and gravel	2	0
Clay and stones	5	6
	16	6

Westwards from Keswick, the following are examples:—

(9.) At How, rather under a mile east of Braithwaite Station:

Sandy clay	2	6
Clay and small stones	5	6
Tough blue clay	15	6
	23	6

(10.) Smithy Green, by the edge of Bassenthwaite Lake:

	ft.	in.
Red sandy clay	4	0
Fine blue clay	18	0
	22	0

(11.) Rather more than a mile east of Cockermouth Station:

Stiff clay and small stones	6	0
Tough blue clay	15	6
	21	6

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From the above sections it will be seen that the blue clay generally underlies a more stony clay or gravelly deposit, though there is no hard and fast line between them. In some parts of the Keswick tunnel-cutting, the clay with imbedded boulders was so stiff that it had to be blasted, and was even then worked through with great difficulty.

3. *Stratified sand and gravel.*—Every here and there, along or at the ends of the principal valleys, are mounds having very much the appearance of moraines, but formed of stratified and false-bedded sand and gravel, generally free from *large* boulders, and sometimes quite free from *any* angular blocks whatever, though large boulders almost invariably occur about and *upon* them. It will be well to mention a few instances of this deposit.

Some low moundy hills, or "Hows" as they are called, occur upon the east side of the Cocker, just where the Lorton Vale opens out into the low country. In a large pit in Cass How by the side of the high road, half a mile north of Lorton, sand and gravel are seen dipping S.W., or down the how-side, at a high angle; the stones are well rounded, but there are *some* subangular blocks about one foot in length. The height above the sea is from 230 to 300 ft.

Between Embleton and Bassenthwaite stations, on the north side of the line, is a deposit of false-bedded sand and gravel resting upon finely stratified sand with clayey bands, and containing *no* boulders or angular blocks; its height is from 250 ft. to 300 ft.

Just above Brigham, Keswick, and south of the railway, stratified sand with sub-angular gravel occurs, containing no large boulders; about 12 ft. of it are seen in a pit.

At the ends of both the Naddle and the St. John's Valleys are long mounds of stratified sand and gravel, with no large boulders *in* but some *upon* them. One of the St. John's Vale mounds stretches straight across the valley from Bridge House to Hill Top, and has evidently been cut through by the stream. In one section, close by the beck, the sand and gravel deposit is seen to rest upon yellow clay with boulders at the level of the water; in another part a small pit shows coarse subangular gravel on 6 ft. of fine, stratified sand, its base not seen. A few large boulders still lie on the surface, but many occur collected along the lines of wall built upon the mound. In both valleys these mounds are at a height of 500 ft.

Another instance of such mounds, though not so long and regular as those just described, occurs at Beckees, a little west of Penruddock Station; one pit shows 8 ft. of sand with a little gravel on the top, but free from boulders, though these occur on the surface; the height here is 860 ft.

Lastly, just south of Troutbeck Station and off the Ullswater Road (west of Mell Fell) there is a series of long mounds of stratified sand and subangular gravel, with some boulders within as well as upon the hillocks; they occur between the heights of 900 ft. and 1,045 ft., but, so far as can be judged by the help

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of the present pits, the contained boulders are larger at the 1,000 ft. elevation than at a less height, this, however, may be due to accident. In the highest pit-exposure one very large boulder occurs, but it is surrounded by subangular stones in a clayey matrix and may be part of a later deposit against the bank of sand and gravel, which only contains much smaller boulders.

d. Conclusions.

The facts now brought forward seem, I think, to warrant the following conclusions:—

At the commencement of the cold period small glaciers occupied the heads of the various valleys, and, as the cold continued and increased, they became larger and larger, until, in many cases, they united, overlapping the lower ridges parting valley from valley, and forming one great confluent ice-sheet, the movement of which was determined to the north and to the south, or east and west—as the case might be, in different parts of the district—by the main watershedding lines. A great quantity of rocky débris was moved onwards and left scattered over the country, partly by the first formed moraines being pushed forward, and partly by the ice overriding the same and dragging on and triturating the fragments beneath it. In this way the Till was formed, sometimes left in rock-sheltered upland hollows, but most largely deposited on the lower and less inclined ground.

Whether this first land-glaciation was interrupted by one or more mild periods, the deposits in this district do not prove, but if it were so in Scotland, as Mr. James Geikie upholds in his admirable work, "The Great Ice Age," it must have been so in England and Wales also, and it is possible that some of the thin seams of sand or sand and gravel, which *very rarely* seem to occur in connection with the Till, may be referred to such periods, though, in the absence of any definite evidence in the shape of fossil remains, indicating a mild climate during the deposition of these sands, it would be very rash to draw any such conclusions from them.

As the final close of this epoch of intense glaciation drew on, moraines were left by the retreating glaciers plentifully scattered in every valley, but the glacial streams and rivers must have made much havoc amongst them, cutting them up and bearing away their material to lower levels.

Then, when the cold had disappeared, began a submergence of the district to a very considerable extent. As the land sank, the old moraine material was sifted, sorted, and partly rounded. At the ends of some of the fiords or straits, sand-bars were formed; but, as there was no floating ice during the earlier stages of submergence, these sand and gravel deposits enclosed no large boulders. The district became gradually converted into an archipelago, and currents circulated among the islands. When depression had gone on to the amount of 1,000 ft. or less, the

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cold returned and ice-rafts bore blocks from one part to another.* In many cases the direction in which currents swept the floating ice was the same as that of the old glaciers, and thus boulders were transported along the same course at different periods and by different means. Sometimes, however, or at certain parts, marine currents bore floating ice, with its boulders, in directions opposed to, or much at variance with, the old glacier courses. Thus when the land stood about 1,200 ft. lower than at present, a current, sweeping the north-western outskirts of the district, carried boulders from Sale Fell southwards on to Broom Fell (4). Not until the submergence reached over 1,500 ft. was there any *direct* communication between the northern and southern halves of the lake district, *except* by the straits of Dunmail Raise. Under such conditions a current very probably ran through those straits from south to north, turning mainly to the east on reaching Keswick Vale, though probably sending a branch off to the west; while other currents may have set through the straits between Skiddaw and Blencathra. The case mentioned of an ash boulder at the upper sources of the Caldew would seem to point to a current having *at one time* passed from south to north, *up* the Glenderaterra Valley and *down* through that of the Caldew. The block could not have reached its present situation from any of the volcanic deposits lying north of Carrock and Comb Height, and is scarcely likely to have come from the very limited *ash* exposures of Eycott Hill, to the south-east of the Caldew at Mosedale. It is not likely that this boulder could have been transported by glacier ice or any form of ice-sheet, because it is in the very midst of lofty mountains which would have produced sufficient ice to have filled the valleys between them and kept out any ice-sheet foreign to this group. Hence, I am inclined to consider this case as a *proof* of submergence to the height of at least 1,300 ft., and of the existence of marine currents passing through the Skiddaw mountain group.

The submergence continued until the land must have sunk more than 2,000 ft. below its present level, as the position of boulders in many parts of the district seems to show, and notably those on Starling Dodd (see page 93, also *Quart. Journ. Geol. Soc.*, vol. xxix. p. 437, and Vol. xxx., p. 96). Then the whole district was represented merely by scattered islands clad in snow and ice, each a little nursery of icebergs.

As the land was re-elevated, the glaciers crept down to the level of the sea, sometimes forming moraines just at the sea-margin, as was the case beneath Wolf Crag, Matterdale Common, when the land stood 1,400 ft. below its present level. During all this time numerous boulders were let fall upon the early-formed mounds of sand and gravel, and as the sea shallowed, more such

* For maps showing probable form of land at different stages of submergence, see papers by the author on "Lake District Glaciation," *Quart. Journ Geol. Soc.*, vol. xxix. p. 422, and Vol. xxxi., p. 152.

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mounds were deposited, now however frequently *containing* ice-borne blocks.

Finally, when the land had regained its former height above the sea, glaciers still lingered in the recesses of the mountains, but this second set of glaciers at no time equalled the first in size. Some, in Borrowdale, were sufficiently large to creep down probably as far as Rosthwaite, and the more or less perfect moraines in every upland valley remain as the last traces of the Glacial Period.

The foregoing is the sequence of events which explains most readily the facts previously given. The Till, mainly the product of the confluent-glacier period. The drift-gravel and the stratified sand and gravel, due principally to marine action. Boulders carried far from the parent rock by glacier-ice at one time, and floating-ice at another. Glacial scratches partly produced by the confluent glaciers, partly by the same set when much diminished in size, and partly by the second set of smaller glaciers; also occasionally made by floating-ice during the period of submergence. Moraines left by the early set of glaciers, much modified by subsequent aqueous action; and more perfect moraines left by the most recent local glaciers.

I think too that the immediate cause of the numerous lake-hollows, *many* of which are now completely filled with stream-borne detritus, was the onward movement of the glacier-ice when at its thickest, as suggested by Prof. Ramsay's theory; for not only are these lake-basins extremely shallow when compared with the heights of the mountains and the thickness of the former ice-sheet, but in most cases the agreement is remarkable between the spots at which the greatest depth of water occurs and those points where from the confluence of several ice-streams or from a narrowing of the valley, the onward pressure of the ice must have been greatest.*

I have sometimes been asked whether the glaciation described in my papers on this district was not wholly belonging to the close of the Glacial Period, and whether previously the whole mountain district had not been overridden by a great ice-sheet from the north? To this I answer that, so far as I am able to speak, there is *no* evidence in the district of such a mountain and valley-ignoring sheet, and not *one* boulder of foreign northern rocks to be found *among* the mountains. Therefore the burden of proof lies with those who advocate this theory.

With times subsequent to the Glacial Period we have little here to do. Stone implements of two kinds have been found in the mountain district; some are of the smooth and polished neolithic type similar to the stone axes from Ireland, figured in Sir J. Lubbock's *Pre-Historic Times*, at page 88 (2nd edit.); others are generally longer, more narrow in proportion to their length, and have a roughly chipped surface. One of the latter kind was

* *See* papers by the author, App. 148 and 153.

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found near the so-called Druid's Circle, Keswick, and another by the side of Loughrigg Tarn. The latter is 11 ins. long, 3½ ins. broad, and 2 ins. deep; two beautiful photographs, giving a front and side view of this splendid specimen, have been presented to the Keswick Museum by Wheatley Balme, Esq.; the side view at once indicates the end used as a handle, the presence of which would seem to show that this was not merely an unfinished implement of the polished class, but was used in its present chipped form; and, indeed, the general shape of the two kinds is tolerably distinct. Several of these old stone implements of the district, and others of bronze, may be seen in the Keswick Museum.*

These celts are mostly formed of the highly altered, felstone-like or flinty ash, which occurs so plentifully about Scafell. Rude stone circles, and many remains of what appear to be stone pit-dwellings occur.† The lakes, although examined in some cases at a very low state of the water, have not yet yielded any relics of ancient pile-dwellings. In later times the Roman occupation left its traces in roads over lofty mountains, and scattered camps and settlements.

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* I may here mention that this museum has been started with the hope of illustrating, as completely as possible, the Natural History of the district. Any help from naturalists visiting the country would be most gladly received, as the working resources are somewhat limited.

† Some of these are now being opened by the Keswick Literary and Scientific Society, at present without much result.

For an account of several forms of celts and other relics found in Cumberland, see "Ancient Stone Implements," by John Evans, F.R.S., Pres. G.S., pp. 87, 95, 106, 107, 121, 137–139, 173, 178, 179, 200, 201, 215, 228, 236, 295, 316.

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CHAPTER XIV.

Relation of Scenery to Geology.

There is no study more fitted to lead to an intelligent appreciation of scenery, than geology. No one can visit the neighbourhood of Keswick with even the rudiments of geological knowledge, without being led at once to enter into the meaning of the beautiful variety in the scene around him. A few examples of the way in which the geological structure has influenced the scenery will now be given, and many more may be noted by the observing traveller.

Two types of Scenery.—If we take our stand upon Friar's Crag, jutting out into Derwentwater, we have before us one of the fairest views that England can give—the lake studded with wooded islets, and surrounded by mountains of varied form and outline. Upon the west side, the mountains, most exquisitely grouped together, have soft outlines, and smooth and grassy slopes, sometimes meeting below to form, as in Newlands Vale, an inverted arch of marvellous elegance and grace; these are of Skiddaw slate, which mostly weathers away in small flakes or pencil-like pieces, giving rise to a clayey and shaly wash at the base of the hills. Upon the east side of the lake and at its head, the case is otherwise; the mountains have generally rough and hummocky outlines, and steep and craggy sides, while their waste lies below in the shape of huge tumbled masses, like ruins of a giant castle; these consist of rocks belonging to the Volcanic Series, which are hard, massive, and well-jointed. Thus we have presented to us two independent types of scenery formed by very distinct classes of rock.

(a.) *Variations in the scenery of the Skiddaw Slate.*

Wherever intrusive igneous masses occur among the Skiddaw Slate, a bolder character of scenery is at once assumed. Thus, the doleritic boss of Castle Head stands out in a bold crag above the surrounding and softer slate, and the igneous dyke forming Friar's Crag serves as a strong lake-wall protecting the softer rock behind it.

Igneous masses upon Hindscarth help in like manner to give a bold and craggy form to parts of that mountain. Upon Dodd, on the south-west flank of Skiddaw, dykes of intrusive trap form well-marked buttresses, adding much to the picturesque character of this conical and wooded hill.

In some parts of the Skiddaw Slate area, however, the mountains present a bold front without the aid of igneous masses. when the slate becomes flaggy and gritty. This is perhaps best seen upon the western flanks of Grasmoor and Whiteside, in the Vale of Lorton; Grasmoor End, in particular, descending in sheer, craggy precipices, above the foot of Crummock, the stony beds dipping to the north and to the south on either side.

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Another thing which frequently affects this class of scenery is the cleavage. Sometimes, as on the south-eastern side of Hindscarth, quite a steep rocky glacis is formed by weathering along the cleavage dip; or streams cut out deep ravines along the same, an excellent example of which occurs in Far Tongue Gill, between Hindscarth and Dale Head. The cleavage occasionally unites with the true bedding, to give a peculiar character to a mountain; of this, Blencathra (Saddleback) is a noble example. It is composed of flaggy and black slate dipping, on the whole, pretty steadily to the north-west at an average angle of 25°, which corresponds with the slope of the back of the mountain (Plate VII.); but crossing this dip, at a higher angle, are the cleavage planes, along which the slate mostly weathers, and thus arise the steep-sided front and sharp edges characteristic of this grand mountain. Sharp Edge, on the north side of Scales Tarn, runs with the cleavage strike, the steep glacis towards the Tarn being formed by the dip of the cleavage at angles of about 45° to 55°. The popular name of this mountain, Saddleback, arose from its saddle-like shape as seen from the east, this being due to a synclinal curve in the bedding between Atkinson Pike and the true summit.

(b.) *Variations in the scenery of the Volcanic Series.*

Here variations are mostly due to the alternations of ash and lava beds, and the varying hardness and amount of cleavage, of the former. The hill-side above Barrow, on the east side of Derwentwater, shows a very marked series of horizontal lines or steps, especially as seen from the lake or its west side, the step-like appearance being due to the alternations of beds of ash and lava of different degrees of hardness, all dipping into the hill at an angle of about 9°. The terraces in quite the upper part of the steep face, called Brown Knotts, evidently mark the various flows of a thick series of lavas, and remind one of the origin of the word trap, from *trappa*, Swedish, a stair.

But perhaps the most striking examples occur in the St. John's and Shoulthwaite Vales. Standing at the north end of the former and looking up-stream to the right hand, the various beds of ash and lava are seen to form a low synclinal along the course of High Rigg (see Section 5, Plate XI.), the harder beds standing out clearly as terraces, sloping according to the dip, and having their course interrupted here and there by faults, which, breaking the continuity of the strata, cause gaps across the hill, and along these the farmers have built straight stone walls, so that the faults are marked on the surface by the lines of wall.

On the east side of the Shoulthwaite Glen, and above the Moss, is a fine hill called the Benn. When viewed from the Ambleside road, a little to the north, the small outlying mass of lava, at the top, is distinctly seen dipping northwards, while a second thick bed, some way beneath, forms a lower, well-marked, craggy zone, softer ash lying between the two. Upon the west side of the glen the same dependence of scenery upon geologic structure may be observed, the massive and more craggy lavas marking the course of a low synclinal, faulted at one or two places.

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Over those parts of the area occupied by the Volcanic Series, where there is a great spread of felspathic ash of a tolerably uniform hardness, and much cleaved, an approximation to the character of the Skiddaw Slate mountains is produced; this may be seen in portions of the Helvellyn range, and here also we find the cleavage often helping to give rise to sharp edges. The best possible examples of this are in Striding Edge and Swirrall Edge, running east from Helvellyn on either side of Red Tarn. In the case of the latter, the *strike* of the cleavage corresponds *exactly* with the direction of the Edge, while the small patch of dolerite, described on page 38, forms a somewhat massive head at the junction of the arrête* with Helvellyn. In the case of Striding Edge, along the sharpest part, the cleavage strike is a little oblique to the direction of the edge, but the ash is tolerably fine and therefore readily flakes away; between High and Low Spying Hows, however, the course of the ridge is again *exactly* that of the cleavage strike, and the manner in which the edge is formed is clearly seen, since all along this part of its course, besides the flaking away of the slate, there are numerous slips now taking place *along the cleavage planes*, especially on the dip side.

(c.) *Effect of Igneous Dykes.*

Intrusive dykes occasionally give point to the scenery in two ways. Sometimes they form rather craggy and conspicuous lines across the country, if harder than the surrounding rocks; but at other times, either from being softer than the neighbouring rocks, or more jointed, they give rise to what are often called "doors," such as Mickle Door, Comb Door, &c.,—squarish openings or longitudinal passages, on a mountain crest or in a line of crags. Mickledoor, between Scafell Pikes and Scafell, through which a narrow dyke runs, not however now occupying the whole width of the chasm, is one example. Another fine instance of a clearly-cut, parallel-sided gap and passage, is to be seen in Brown Cove Crags, just west of Helvellyn Low Man, the dyke occasioning it being a branch from that of Armboth and Helvellyn. Occasionally these "doors" occur, and yet no dyke can be seen, owing to the quantity of rocky débris fallen from the crags on either side.

(d.) *Glacial action.*

Of the effects produced in the scenery by glacial action it is hardly necessary to speak. Among the harder beds—those of the Volcanic Series—the rounded form of every rock and hummocky outline of the lower ridges, is sufficiently evident on all sides.† Sometimes also the groups of old moraines form conspicuous objects in the scenery, as at the head of Ennerdale, in Longstrath, Greenup Gill and Wyth Burn Valleys (Fig. 5, Plate VI.), &c.; while perched blocks not unfrequently attract the eye and add much to the interest of the scene (Fig. 4, Plate VI.).

* Cumberland, "*arridge.*"

† Not seldom the ice has worked up the dip-slope of beds; this is markedly the case in Borrowdale, beneath Castle Crag, and may be partly seen in the example from Glaramara (Fig. 4, Plate VI.).

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(e.) *Effect of modern denudation.*

A common characteristic of the scenery over the whole district is the frequent occurrence of old lake sites, generally forming stretches of rich alluvial land in the valleys, and peat mosses upon the fells. The amount of material brought from higher to lower levels since the lakes occupied these sites, must be enormous, and none can live long in this or in any mountainous country without being impressed by the immense power of atmospheric denudation acting throughout long periods. The screes, as the slopes of fallen fragments are called, are well-known features in the mountain landscape. Also, down the steep hill flanks, occasional flood-streams will pile up the washed-down débris on either side of them, giving the appearance of long trenches with the matter thrown out on either hand.* Dry deltas, formed where small valleys open into larger ones, are often prominent objects; of such, there is a good example just where the Liza issues from between Grasmoor (11) and Whiteside (10). It was down this valley a great flood swept on the 9th of September 1760, caused by the bursting of a water-spout at its head.† A similar flood occurred in the Vale of St. John on August 22nd, 1749; of this an old account relates:—"Several thousands of huge fragments of broken rocks were driven by the impetuosity of these dreadful cataracts into the fields below, and such was their bulk that some of them were more than 10 horses could move, and one measured fairly 19 yards in circumference."‡

Lastly, there is a certain *blocky* structure common to several of the mountain tops, and notably Scafell Pikes, which is of considerable interest and gives great character to some of the scenic foregrounds. Fragments of all sizes and shapes lie thickly strewn upon the surface, so that progression is limited to a jumping motion from block to block. I think that this peculiar structure is due to the opening out of numerous fissures along and across the mountain tops, into which the well-jointed rocks have fallen on either side. These fissures may be studied in all phases of their formation, and sometimes occur even along the summits of lofty flat-topped mountains, in situations where it is difficult to conceive of the formation of ordinary slips, which however often enough occur on a large scale along the mountain flanks.§ It seems to me likely that some of this fissuring may be due to earthquake-shocks taking place since the glacial period, and the scarcity of *nicely*-poised perched blocks may be owing to the same cause.

Much might be written on the scenery of the Lake-district considered geologically, and the notes here given must be regarded as merely suggestive. The observing traveller will, however, find more pleasure in discovering the reasons of things for himself, than in having them all pointed out in guide-book fashion beforehand.

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* It seems to be this same sort of action, only heavy rain instead of a continuous stream, which produces that strange appearance upon many of the fell-tops, or sides, as if stones had been sown along regular lines close together.

† App. 4. ‡ App. 3 and 5.

§ "Rock Fissuring," *Geol. Mag.*, vol. x., App. 66.

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CHAPTER XV.

Fossils of the Skiddaw Slate.*

The Skiddaw Slate has hitherto been very unproductive of fossils. Where the cleavage crosses the bedding there is very little chance of any being detected, but in those parts where the two structural planes coincide, or the cleavage is undeveloped, they may be occasionally found on a somewhat diligent search. The following list is compiled from various sources, Dr. Nicholson's valuable papers being the chief; and a few fresh forms are added from observations made during the progress of the field-work.

Hydrozoa.

Graptolitidæ.†

Dichograptus annulatus, *Nich.*
——— gracilis, *Nich.*
——— multiplex, *Nich.*
——— octobrachiatus, *Hall.*
——— reticulatus, *Nich.*
Loganograptus Logani, *Hall.*
Tetragraptus bryonoides, *Hall.*
——— crucifer, *Hall.*
——— Headi, *Hall.*
——— quadribrachiatus, *Hall.*
Phyllograptus angustifolius, *Hall.*
——— typus, *Hall.*
——— Anna, *Hall.*
Thamnograptus Doveri, *Nich.*
Trigonograptus lanceolatus, *Nich.*
Climacograptus antennarius, *Hall.*
——— teretiusculus, *His.*
——— bicornis, *Hall.*
Diplograptus armatus, *Nich.*
——— Hopkinsoni, *Nich.*
——— mucronatus, *Hall.*
——— pristiniformis, *Hall.*
——— pristis, *His.*
Didymograptus affinis, *Nich.*
——— bifidus, *Hall.*
——— fasciculatus, *Nich*
——— geminus, *His.*
——— gibberulus, *Nich.*
——— nitidus, *Hall.*
——— patulus or extensus, *Hall.*
——— serratulus, *Hall.*
——— sextans, *Hall?*
——— V.-fractus, *Salt.*
——— divaricatus, *Hall.*
Pleurograptus vagans, *Nich.*
Dendrograptus Hallianus, *Prout?*
Graptolithus tenuis, *Portl.*
Azygograptus Lapworthi, *Nich.*

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* Papers on Skiddaw Slate Fossils, see App. 2S 40, 42, 43, 46, 49, 54, 58, 63, 64, 64*a*, 68*a*.

† Compiled from Dr. H. A. Nicholson's Monograph, *loc sit.* A fine collection of graptolites in the possession of Kenzie Dover, Esq., contains specimens that would seem to indicate that some of the Didymograpsi attained a gigantic size, as much as two feet in length, and many of the straight fragments found in the slate may possibly be portions of such, the radicle being only occasionally preserved.

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BRACHIOPODA.

Discina (?).
Lingula brevis, *Portl.*

ANNELIDA.

Worm-tracks and burrows.
Palæochorda major, *McCoy.*
——————— minor, *McCoy.*
Chondrites acut-angulus, *McCoy.*
——————— informis, *McCoy.*
Arenicolites.
Scolites.
Helminthites, *Salt.*
Stella-scolites radiatus, *Ether.*

CRUSTACEA.

Trilobita.

Æglina binodosa, *Salt.*
——— caliginosa, *Salt.*
——— sp? *Ether.*
Agnostus Morei, *Salt.*
Phacops Nicholsoni, *Salt.*
Trinucleus Gibbsii, *Salt.*
Ogygia.?
Calymene brevicapitata.?, *Portl.*
Asaphus peltastes, *Salt.*
———? *Ether.*
Niobe Doveri, *Ether,*
Cybele ovata, *Ether.*

Phyllopoda.

Caryocaris Wrightii, *Salt.*
——————— ova of?
Ceratiocaris? sp., *Baily.*

Ostracoda.

Leperditia?

PLANT REMAINS.

Buthotrephis flexuosa, *Hall.*
——————— Harknessi, *Nich.*
——————— (?) radiata, *Nich.*
Eophyton (?) palmatum, *Nich.*
Chondrites (?).

Geological age of the Skiddaw Slates.—This formation, once regarded as azoic, has now yielded a sufficient number of fossils to allow of its approximate age being determined. Mr. Salter long since considered it to be of L. Llandeilo age, and the researches of Dr. Nicholson inclined him to the same opinion.

It will be necessary to suspend judgment upon the complete correlation of the divisions of the Skiddaw group with those of the Lower Silurian in other districts, until the whole of the Cumbrian area has been surveyed, and detailed comparisons instituted with the rocks of the Isle of Man and the South of Scotland, as well as with those of Wales.

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* Quart. Journ. Geol. Soc., vol. xxxi., p. 167.
† *Ibid.*, p. 631.

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The following is a list of localities where Skiddaw Slate fossils have been found within this area :—

Skiddaw, Randel Crag.	Graptolites.	Trilobites.	Fucoids (?).
,, *Gibraltar Crag.*	,,		
,, *White Horse.*	,,		
,, *Sand Beds.*		Phyllopods.	
,, *How Gill (above and east of).*	,,		
Blencathra; summit.	,,	Trilobite.	
Bannerdale Fell.	,,		
Barf. *Lingula brevis.*	,,		
Whiteside. ,,	,,	Trilobite.	
Grasmoor.			Plants (?).
Cat Bells.			,,
Outerside. *Lingula brevis.*	Graptolites.	Phyllopods.	
Barrow.	,,		
Swinside.			Plants (?)
Hodgson How.	Graptolites.		
Mosedale Beck.	,,		
Trout Beck; Pencil Crag.	,,		
Threlkeld Common.		Trilobite.	
Near Peel Wyke (Bassenthwaite Lake).	Graptolites.		Plants (?)
Scale Hill.	,,		
Braithwaite Brow.	,,		
Whit Beck, Flag Quarry, near High Lorton.	,,		
Latrigg (back of).			Fucoids (?)
Sandy Beck, Wood, 3 miles S. of Cockermouth.	,,	Trilobite.	
Lonscale Fell.	,,		
Smithy Fell, Mosser.	,,		
Latterbarrow (shell in grit).			

Worm-tracks are pretty frequent at all localities and the remains of phyllopod crustacea occur in most parts where any fossils are to be found.

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APPENDIX A.

Description of New Fossils occurring in the Arenig or Skiddaw Slates. By R. Etheridge, F.R.S., &c., Palæontologist to the Geological Survey of Great Britain.

Early in the present year Kenzie Dover Esquire, sent to us through Mr. Ward many graptolites, some new and singular species of Trilobita, and a peculiar rayed body of considerable size, all from the Skiddaw Slates. Much interest is attached to this rayed or stellate form from doubts as to its being truly of organic origin, or merely mechanically formed through the agency of some Annelide or even a cast of some large fucoidal plant allied to the living Laminaria; this latter view, however, being very doubtful, I have sought for and exhausted every available source of information both foreign and British for some elucidation of its history, structure, and affinity, but without success.

This singular rayed body seems allied to a group of forms common in the *Potsdam Sandstone, Calciferous Sandstone, Trenton Limestone, Hudson River* group, and *Clinton* beds of Canada, and the United States. Prof. J. Hall in 1847* described some singular forms to which he gave the name Palæophycus from the seaweed-like aspect of the markings upon certain of the rocks, except that all his forms were not radiated; they have, however, a similar facies and perhaps similar origin. In 1852 Hall named and described other similar bodies, calling them Rusophycus; these resemble short or tumid cruzianæ. In 1846 he established the genus Buthotrephis for a group of digitate and palmate bodies, plants (seaweeds) or Annelide castings still more resembling our Skiddaw specimen; to whatever group in the vegetable or animal kingdom these forms are to be referred, their range in time was considerable, the sandstones and impure limestones of the New York series, from the Potsdam Sandstone to the Clinton beds, more or less containing them. Looking at this fossil from the botanical or plant point of view, I consulted Mr. Carruthers, F.R.S., of the British Museum, who at once agreed with me that there were grave objections to placing it in the vegetable kingdom, or correlating it with any known plant, ancient or modern; he, however, kindly placed at my disposal two specimens from the Millstone Grit of the north of England, and their affinity with the Skiddaw specimens is remarkable and help to somewhat determine its place systematically; in one of these the elevated and radiate condition and structure from the centre to the circumference is complete and perfect, the base, which has been cut and polished, shows no less than 22 apparently doubly perforated tubes or rays, or if single 11; there is some difficulty in determining this, as on the exterior the chief rays are 10 or 11 and they appear to bifurcate immediately on leaving the apex. The second specimen lent me by Mr. Carruthers, equals in size our form from Skiddaw, and although only a portion of the entire body, it must when originally formed have been almost identical with our Skiddaw specimen.

The above forms would probably be included or placed by Hall with the Plantæ and amongst the Fucaceæ; doubtless they much resemble in form the basal or attached portion of the great Laminaria, common on our shores (in the Laminarian Zone), the organic part having become decomposed and leaving casts only in sand (now sandstone). It is impossible to distinguish whether the Skiddaw specimens were ever hollow or solid, being so compressed, or whether the whole body was conoidal in form or depressed, or whether the rays were arranged in single, double, or more layers or tiers; from its present condition it appears to have had only a single series of radiating branches, roots, or burrows, these differing from those found in the Millstone Grit, which are arranged in two or three layers. The surface of the rays seem at first sight to be ornamented or delicately sculptured with longitudinally crenulated lines; this, however, is not

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* Nat. Hist. of New York, pt. 6. Palæontology, Vol. 1, p. 7.

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organic but due to the nature of the matrix, which is an extremely fine grained and highly levigated condition of the slate. A peculiar condition of cleavage seems to be the cause of this marking. Whether the rays were originally hollow or solid we have no means of determining; their present condition gives no evidence of any outer structure or dermal covering wall or pellicle, nor can any evidence of carbonized matter be detected at the broken terminal ends visible in one or two of the rays. Prof. Phillips in the year 1848 obtained an oval disc-shaped body from the upper part of the Upper Ludlow series at Perton near Stoke Edith in the Woolhope area, this he named Actinoplyllum plicatum, believing it to be of vegetable origin; he also referred it to the singular forms Acetabulum and Polyphysa. Actinophyllum was much smaller, and the extremities of the rays slightly lobed and revolute, and the rays themselves not so flat as our Skiddaw body, and were 36 in number instead of 16; a slight carbonaceous pellicle seems to have accompanied Actinophyllum; no such occurs in our specimen, I refer to this genus of Phillips* for comparison, with which in some respects it agrees.

It will be seen that we have no evidence for placing it in the vegetable kingdom or directly as an organised body in the animal kingdom, at the same time its origin may be due to the latter as one of the many forms produced through the agency of the Annelida, being indeed caused by the castings or burrowing of some marine annelide whose symmetrical habitation has resulted in the radiated form under notice. The genus Rhizostoma suggests itself as having some relation, so far as form is concerned, but until the Solenhofen beds (of Kimeridge Age) were discovered we knew of no medusoid occurring in a fossil state; and form alone will not, or must not, guide us in the determination of obscure traces of life in these oldest rocks.

Sub-Kingdom ANNULOSA.

Class ANNELIDA.

STELLA-SCOLITES, gen. nov.

General Description.—Body, disk-like, rayed, the rays proceeding or radiating from a central round space at the apex, rays 16 in number, narrow at junction with the central space or cavity, becoming broad and nearly flat or spathulate at their extremities, which also appear to have been rounded; diameter 8 to 10 inches, but from the mode in which the rays are lost in the matrix, they may have extended beyond that which now appears to be the margin, border, or extent of the rays.

This so far unique form I refer to the operation of some marine annulose animal belonging to the Annelida, probably one of the Errantia (Dorsibranchiata), to which also belongs Arenicola, Nereis, and Aphrodita. In the Cambrian, Silurian, and Carboniferous, and indeed all arenaceous rocks of Britain we have much evidence of the habits and labours of the annelida, the tracks and castings of which have received the names of Arenicolites, Scolites, Vermiculites, Crossopodia, &c., and much of their history has been written by Salter and others, so as to leave no doubt as to the important part these organisms did and still do play in the sandy and muddy deposits (future strata) accumulated along our coasts in almost every estuary or flat sandy foreshore, or that part exposed between tide marks, and called the littoral zone.

The filling in of the tubes or casts is usually of coarser material than the matrix surrounding the tracks, tubes, or borrows, &c., clearly showing that the infilling was subsequent to the labour of the Annelide.

This may be a burrow of complicated structure, and due to the presence and action of one or many Arenicolæ in a group; Dr. Kinahan, in the Proceedings of the Dublin Geological Society for 1857, 1858, has described burrows of many kinds, conical, horizontal, vertical, oblique, &c.

In Chondrites it is probable that the markings are the contents of worm tubes or the rejectamenta from the bodies of the Annelida as they fed upon and worked their way through the silty or muddy deposits, in other words they probably fed upon the mud, and abstracted food in the process, the Diatomaceæ or some of the soft Rhizopoda being generally present in such deposits.

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* Mem. Geol. Surv., Vol. 2, pl. 1, p. 386, 1848.

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STELLA-SCOLITES RADIATUS, sp. nov. Plate XIII.

Body radiated or stellate, composed of 16 radiating rays nearly all of equal length, and proceeding from a central depression, the nature of which cannot be determined. Extremities of the rays appear to be spathulate, whether originally hollow or solid we are not able to state, apparently, however, they were tubular; the rays appear to meet with much regularity around the central space, which is filled with the matrix so that its true character is doubtful.

No structure whatever can be detected on the exterior of the rays, the apparent sprinkling spread over the surface being purely physical, and due to cleavage associated with the very finely divided nature of the argillaceous matrix; neither have we means of ascertaining whether the rays were tubular, the specimen not being our own we did not venture to make any section. Other and similar forms from the Millstone Grit show them to be distinctly tubular or hollow, even bifurcating; additional specimens may throw more light upon the condition of their structure.

Sub-Kingdom ANNULOSA.

Div. ARTHROPODA or ARTICULATA.

Class CRUSTACEA.

Order *Trilobita.*

Occurring with the radiated Annelide, and from the same beds, Mr. Dover has obtained three Trilobites all apparently new; the largest of the three seems to differ from any known genus, but being a mould or impression of the original form, it is only from a cast made in gutta percha that our description can be drawn up; all details or markings upon the impression of test or shell are lost, and besides an obscure glabella only part of the axis or middle segment of the body is preserved.

The two other Trilobites are somewhat more determinable, and appear to be new to the area. I do not feel sure as to whether the Crustacea belong to primordial genera (Upper Cambrian) or not; they much resemble Tremadoc forms and Fig. 2., Plate XII., apparently one of the Asaphidæ, approaches very closely to, if not identical with, Niobe, to which genus I refer it.

Fam ASAPHIDÆ.

Niobe Doveri, sp. nov. Plate XII., Fig. 2.

Body broad, ovate, depressed, length 1½ inches; head semi-oval and nearly half as wide again as long, somewhat lunate in shape, head angles short and closely oppressed to the pleuræ; glabella broadly rounded or clavate, indistinctly marked, furrows in two pairs, the lower horizontal, the upper pair diverging upwards, eyes very indistinct, facial suture nearly obsolete or very indistinct; axis broad and tapering, thorax composed of six segments or somites; pleuræ little more than half the width of axis, they appear to be facetted and rounded at their extremities, and the fulcrum is near the axis; pygidium large, semicircular and flattened, with a short, broad, and tapering axis, having six segments, pleuræ composed of three broad segments which only reach or extend to the inner edge of the broad and flattened margin or caudal fascia, which is of equal width all round.

The thoracic segments appear to have been tuberculated, a single round tubercle occurring on each segment near the suture or axial furrow, none on the segments of the pygidium.

The pleuræ are so indistinct that it is impossible to state their true nature. Eyes very indistinct, but appear to be marginal and half way up the head.

Our specimen strongly resembles Niobe, especially so as regards the pygidium and glabella, but its badly preserved condition almost forbids comparison with that genus or even Barrandia; neither genus, so far as we know, has yet been recorded from the Skiddaw Slates.

Barrandia, with one exception, is essentially a Llandeilo form. Mr. Hicks has lately obtained a new species which he has named B. Homfrayi, it occurs in the Arenig beds of Llanviran, St. Davids. Niobe is essentially a Tremadoc genus, three species only being known. The glabella of our species appears to have been widely clavate, and the facial suture marginal, whether the pleuræ are falcate or facetted it is impossible to determine. The pygideal pleuræ do not reach beyond the inner edge of the somewhat broad, flattened margin or caudal fascia as in Niobe; whether the flattened area was striate or

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not cannot now be determined. It would appear from the above that it is not improbable that the upper Tremadoc beds may be present in the Lake area, the genera, Æglina, Niobe, or Barrandia being significant forms, and they offer a stimulus to further research. We dedicate this species to K. Dover, Esq., through whose liberality in forwarding his collection for examination we have been enabled to name it.

Loc., in the scree* below Randal Crag, Skiddaw; formation, Skiddaw Slates.

Fam. ASAPHIDÆ.

Æglina, sp.? . Plate XII., Fig. 3.

I was in doubt whether to refer this unsatisfactory specimen to Æglina or Remopleurides, the axis and large cephalic shield resembling either genus. The thoracic or body rings in form and number (6) approach and resemble Æglina, and the pleuræ (what remains of them) are two thirds the width of the axis, and also resemble those of Æglina. The chief generic character is unfortunately very indistinct, the faintest remains of the large reticulated eyes being barely recognizable only along the left cheek; the pleuræ are not sufficiently well preserved to show the nature of the grooves and facets which are characteristic in well preserved specimens, the tail segments and pleuræ are too indistinct for description, and thus the cephalic shield, the thoracic segments and remains of the eye are the only characters that enable me to decide as to the genus. In outward form it is closely allied to Æglina binodosa, which species is said to occur in the Skiddaw Slates (Lower Llandeilo) associated with Agnostus Morei, Caryocaris Wrightii, and a doubtful species of Ogygia; the rather broad pleuræ, and number of somites, remove it from Remopleurides, and the faint traces of the eye seems sufficient to determine this unsatisfactory specimen to be Æglina. I cannot venture to give it any specific name, but refer it to Æglina binodosa.

Loc., Great Knott, near Randal Crag, Skiddaw; formation, Skiddaw Slates.

Fam. ASAPHIDÆ.

Asaphus. Plate XII., Fig. 1.

The members of this large family differ so much amongst themselves, and yet in many points so strongly resemble each other, that any abnormal condition due, either to cleavage or preservation, tends to cause extreme doubt as to generic value. This large specimen from Skiddaw is evidently one of the Asaphidæ, a family comprising the most expanded and massive Trilobites of the order or group. They are readily distinguished by the size of the cephalic shield and pygidium, and by the comparatively few thoracic segments, seldom numbering more than eight. Mr. Dover's specimen is only an impression or mould in the slate, and shows no characteristic markings whatever. I, however, draw up the best description I can.

Body elongated, slightly convex; head or cephalic shield nearly one third length of entire body, no character to enable us to determine its original structure; glabella obsolete, no lobes or furrows visible; eyes apparently reniform, large, remote, and about half up the head, with indistinct traces of the facial suture; thorax, seven or eight segments broad, and the sutures between each segment deep; pleuræ quite indeterminable, and we therefore have no means of arriving at the nature of the fulcra or facets; pygidium not preserved.

Remarks.—It is possible this specimen is both elongated and depressed, being cleaved in the direction of its longer axis, thus giving undue length to the cephalic shield, which from its form and structure would show extension in greater proportion than the body segments. The tail if present would have tended to still better illustrate the true or original form of the Trilobite; unfortunately that portion is lost. I am disposed to believe that this specimen must have been 9 inches in length when living, as the pygidium is usually as large, and in some species longer, than the cephalic shield.

* This is a Cumberland word to denote fallen fragments lying on a slope.

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It would be unwise to attach any specific name to this single and imperfect form in which no character is determinable. We hope better may be found.

Fam. CHEIRURIDÆ.

Cybele ovata, sp. nov.

Body broadly ovate or obtusely tapering to the caudal extremity, only the external portion of the cephalic shield and left cheek shown, and this is denuded of its outer shelly covering, it must however have been nearly semicircular; lateral angles very short, barely spinose, base of the glabella seen only; thorax consists of 12 segments with narrow axis which appears to have been tuberculated; pleuræ double the width of axis, nearly flat, curved downwards from seventh segment, the ends are free and bluntly pointed, the extremities of the seven upper pleuræ curve upwards; the whole surface appears to have been rather minutely tuberculated; pygidium is composed of three or four segments with narrow axis and rounded like the thorax and continuous with it; the pleuræ much curved downwards parallel to the axis, the lower pair meeting beneath the mucro.

We have no means of determining the nature of the cephalic shield, consequently the form and nature of the glabella with its lobes and furrows are yet to be ascertained. The species, however, differs essentially from the two known forms C. rugosa and C. verrucosa, species not at present known below the Caradoc rocks. To neither of the above can our form be referred.

Loc., Sandy Beck, near Wood, south of Cockermouth; formation, Skiddaw Slates. Obtained by Mr. Birkett, to whom we return our thanks for allowing us to examine and describe the species. Unfortunately it came too late to be inserted in the plate and accompany the other Trilobites.

All the above specimens except Cybele ovata were kindly submitted to us by Kenzie Dover, Esq., and as they are new forms Mr. Ward was anxious to have them figured and described in the present memoir. The Trilobites are scarcely well enough preserved to do more than record them as differing from known forms. The stellate body to which I have ventured to assign a name and systematic place is open to criticism, but there is no evidence whatever to show whether it be plant or animal, and by analogy only with other and similar bodies which occur in the Slates and Millstone Grits of the north of England do I refer it to the annelida. It is to be hoped Mr. Dover may obtain more definite specimens to illustrate its history.

R. ETHERIDGE.

NOTE.—Since writing the description of Stella-scolites, I have had the opportunity of seeing, through the kindness of H. Woodward, Esq., F.R.S., a cast of (in plaster) a very remarkable sponge, said to come from the Lower Silurian Strata of Franklyn Co., Kentucky. The resemblance to the Skiddaw specimen in the possession of Mr. Dover, and now figured on Plate XII., is so striking, that I am compelled to notice it. The cast in question is nearly 12 inches in diameter, and appears to have been in its living state, and fossil condition, hollow. There are eleven radiating digitations, and which, like the body, are all hollow, meeting at the summit in the form of a broadly depressed cone or dome; there appears to be evidence of bifurcation at the extremity of each hollow ray or digitation, which condition is indistinctly observable in Stella-scolites, and which I have described as probably spathulate. I also questioned the solid or hollow nature of the rays in Stella-scolites, believing them to have been tubular. Should the Skiddaw specimen turn out to be a sponge and have hollow rays, it may enable us to correlate it with the Amorphospongia from Kentucky. No spiculæ could be observed in Stella-scolites, although looked for in and around the specimen. The cast of the Kentucky sponge (if sponge it be) is like the original, broken, and open at the summit, and shows the passage of the hollow rays into the general body-cavity.

When at Bangor this summer examining the coast sections, the fore-shore of the Menai Straits was literally covered with conical radiating annelide burrows, which in appearance and habit I could not distinguish from my genus Stella-scolites, and I have yet to be convinced that the so-called Amorphospongia of Franklyn Co. belongs to the order Spongida. R.E.

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APPENDIX B.

List of Works and Papers bearing on the Geology of the Keswick or Northern District of the Lake Country.

Note.—The list of papers here given is divided into several parts.

a. Index of authors, with the numbers of their papers.

b. Works and papers on the *General Geology* of the Keswick District.

c. Works and papers on the *Mining* of the Keswick District.

d. Works and papers on the *Glacial Geology* of the *Lake* District.

Under the head of (*b*), *all* the papers refer to strata below the Coniston Limestone, and their associated igneous rocks, as the newer formations have scarcely been touched upon in the present Memoir. The same may be said of those under (*c*).

I am greatly indebted to Mr. Whitaker for help in drawing up this list.*

(*a.*) Index of Authors, with the Numbers of their Papers.

A.

Agassiz, Prof., 97.
Anon., 5, 7, 72, 75, 80, 92.
Aveline, W. T., 50, 62, 62*a*.

B.

Beaumont, E. de, 83, 88*a*.
Bonney, F. G., 109.
Brayley, E. W., 78.
Britton, J., 78.
Brocklebank, 116.
Bryce, Dr. J., 99, 101.
Buckland, Rev. Dr. W., 96.

C.

Cameron, A. G., 126.
Chambers, R., 100, 102.
Clarke, Prof. E. D., 85.
Conybeare, Rev. W. D., 13.
Coste, 88*a*.
Croll, J., 127.
Curry, J., 111.

D.

Dakyns, J. R., 51, 52, 69.
Davy, Dr. J., 35*a*, 98, 103, 104.
De Rance, C. E., 112, 128, 129, 130, 131.
Dickinson, W., 30.
Dufrénoy, P. A., 83, 88*a*.

E.

Evans, J., 62*b*.

G.

Gilpin, 3, 4.
Goodchild, J. G., 93*a*, 146, 150.
Gray, T., 2.

H.

Harkness, Prof. R., 37, 42, 43, 45, 46, 59, 117.
Hodgson, Miss E., 118.
Hopkins, W., 20, 27.
Hopkinson, J., 58, 64*a*, 68*a*.
Housman, J., 6.
Hughes, Prof. T. McK., 47, 62*a*.
Hull, E., 44, 105, 106.
Hutchinson, W., 77.

J.

Jameson, J., 81.
Jars, 76*a*.
Jenkinson, 65.

K.

Kendall, J. D., 93*b*.

L.

Lapworth, C., 68*a*.
Linton, Mrs. E. L., 44.

M.

Mackintosh, D., 107, 113, 114, 119, 120, 121, 132, 133, 134, 139, 141, 147, 151.
Marshall, J. G., 38, 41.

* Any additions or corrections would be welcome.

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N.
Nicholson, Dr. H. A., 46, 48, 49, 49*a*, 53, 54, 55, 56, 57, 59, 60, 63, 64, 65*a*.

O.
Otley, J., 8, 9, 10, 12, 82, 84.

P.
Parson and White, 11.
Pattison, S. R., 115.
Perdormet, — 88*a*.
Phillips, Professor J., 23, 36, 39, 95, 108, 110.

R.
Ransome, T., 90.
Robinson, Rev. T., 73.
Ruthven, J., 33, 34.
Rutley, F., 135, 136.

S.
Salter, J. W., 40, 46.
Schrader, — 79.
Sedgwick, Rev. Prof. A., 14, 15, 16, 17, 18, 19, 21, 22, 24, 26, 28, 31, 32, 35, 37*a*, 91, 94.
Sharpe, D., 25, 29, 21*a*.
Short, Dr. T., 76.
Smith, Wm., 1.
——, J. L., 93.

T.
Thomson, Dr. T., 89.
Tiddeman, R. H., 140, 142, 143.
Tooke, A. W., 88.

V.
Vanuxem, L., 86, 87.

W.
Ward, J. C., 61, 66, 67, 68, 69, 70, 71, 71*a*, 71*b*, 122, 123, 144, 145, 148, 149, 150, 152, 153, 154.
Wollaston, G. H., 124, 137.
Wood, S., jun., 125, 138.
Wright, B. M., 65.

(*b.*) Works and Papers on the **General Geology** of the Keswick District.

1740.

1. Smith, William - Geological Map of Cumberland and Westmoreland. *Lond.*

1769.

2. Gray, Thomas - Journal of a Tour in the North of England (Letters).

1772.

3. Gilpin's - - - Guide to the Lakes. Account of a Water Spout in the Vale of St. John in 1749, *vol.* ii., *p.* 36.
4. ——— - - - Account of a Water Spout on Grasmoor in 1760, *vol.* ii., *p.* 4.

1796.

5. Anon. - - - Guide to the Lakes, by the author "The Antiquities of Furness." Flood in St. John's Vale. *6th edit., p.* 140.

1800.

6. Housman, J. - - A Topographical Description of Cumberland, Westmoreland, Lancashire, and a part of the West Riding of Yorkshire (Map of the Soils, Accounts of Caves, Soils, Minerals, &c.). 8*vo. Carlisle.* Part reprinted under title, "Descriptive Tour, &c.," in 1808 (ed. 3), in 1814 (ed. 6), in 1816 (ed. 7), and in 1817 (ed. 8).

1801.

7. Anon. (D. J. P.) - Some observations on the Agitations of the Lake of Derwentwater, and its Floating Islands. By a correspondent. *Phil. Mag., vol.* xi., *p.* 163.

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1819.

8. OTLEY, J. - - - Account of the Floating Island in Derwent Lake, Keswick. *Mem. Lit. and Phil. Soc., Manchester, ser.* 2, *vol.* iii., p. 64.

1820.

9. ——— - - - Remarks on the Succession of Rocks in the District of the Lakes. *Phil. Mag., vol.* lvi., *p.* 257 (*from the Lonsdale Magazine, vol.* i., *p.* 433).

1827.

10. ——— - - - A concise description of the English Lakes and adjacent mountains. 8*vo., Keswick, 6th edit. in* 1837.

1829.

11. PARSON AND WHITE - History, Directory, &c. of Westmoreland and Cumberland, with a descriptive and geological view of the Lakes, &c. 8*vo.*

1831.

12. OTLEY, J. - - - Further observations of the Floating Island of Derwentwater, with remarks on certain other phenomena. *Mem. Lit. and Phil. Soc., Man., ser.* 2, *vol.* v., *p* 19.

1832.

13. CONYBEARE, REV. W. D. Inquiry how far the Theory of M. E. de Beaumont concerning the Parallelism of Lines of Elevation of the same Geological Era is agreeable to the Phenomena as exhibited in Great Britain. *Phil. Mag., ser.* 3, *vol.* i., *p.* 118.

14. SEDGWICK, REV. PROF. A. On the Geological Relations of the stratified and unstratified groups of rocks composing the Cumbrian Mountains. *Proc. Geol. Soc., vol. p.* 399.

1835.

15. ——————— Remarks on the Structure of large Mineral Masses, and especially on the chemical changes produced in the Aggregation of Stratified Rocks during different Periods after their deposition. *Trans. Geol. Soc., ser.* 2, *vol.* iii., *p.* 461. (Cumberland, p. 469.)

1836.

16. ——————— Introduction to the general structure of the Cumbrian Mountains, with a description of the great Dislocations by which they have been separated from the neighbouring Carboniferous chains. *Trans. Geol. Soc., 2nd ser., vol.* iv., *p.* 47.

17. ——————— Extrait d'une lettre á M. E. de Beaumont (in the succession of rocks in Cumberland and Wales). *Bull. Soc. Geol. France, t.* vii., *pp.* 152–5.

1838.

18. ——————— A synopsis of the English Series of stratified Rocks inferior to the Old Red Sandstone, with an attempt to determine the successive natural groups and formations. *Proc. Geol. Soc., vol.* ii., *p.* 675.

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1841.

19. SEDGWICK, REV. PROF. A. - Supplement to "Synopsis of the English Series," &c. *Proc. Geol. Soc., vol.* iii., *pt.* ii., *p.* 545.

1842.

20. HOPKINS, WM. - On the Elevation and Denudation of the Lakes of Cumberland and Westmoreland. *Proc. Geol. Soc., vol.* iii., *p.* 757. (*See also* 1848.)

21. SEDGWICK, REV. PROF. A. - Three letters on the Geology of the Lake District in Wordsworth's description of the Scenery of the Lakes. 8*vo. Kendal.* Subsequent editions in 1843, 1846, and 1853.

1843.

21*a*. SHARPE, DANIEL - On the Silurian Rocks of the South of Westmoreland and North of Lancashire. *Proc. Geol. Soc., vol.* iv., *p.* 23.

1845.

22. SEDGWICK, REV. PROF. A. - On the comparative classification of the Fossiliferous Strata of N. Wales, with the corresponding deposits of Cumberland, Westmoreland, and Lancashire. *Quart. Journ. Geol. Soc., vol.* i., *p.* 442.

1846.

23. PHILLIPS, PROF. J. - Geology of Lake District in *Black's Guide.* (15th edit. in 1868.)

24. SEDGWICK, REV. PROF. A. - On the classification of the fossiliferous slates of Cumberland, Westmoreland, and Lancashire, *Quart. Journ. Geol. Soc., vol.* ii., *p.* 106.

25. SHARPE, DAN. - - On Slaty Cleavage. *Quart. Journ. Geol. Soc., vol.* ii., *p.* 74.

1847.

26. SEDGWICK, REV. PROF. A. - On the classification of the fossiliferous slates of N. Wales, Cumberland, Westmoreland, and Lancashire. *Quart. Journ. Geol. Soc., vol.* iii., *p.* 133.

1848.

27. HOPKINS, WM. - - On the Elevation and Denudation of the Lakes of Cumberland and Westmoreland. *Quart. Journ. Geol. Soc., vol.* iv., *p.* 70. (*See also* 1842.)

28. SEDGWICK, REV. PROF. A. - On the organic remains found in the Skiddaw Slate, with some remarks on the classification of the older rocks of Cumberland and Westmoreland. *Ibid., p.* 216.

1849.

29. SHARPE, DAN. - - On Slaty Cleavage. *Quart. Journ. Geol. Soc., vol.* v., *p.* 111.

1852.

30. DICKINSON, WM. - On the Farming of Cumberland [with description of the strata and soils]. *Journ. Roy. Agricult. Soc., vol.* xiii., *p.* 207.

31. SEDGWICK, REV. PROF. A. - On the classification and nomenclature of the Lower Palæozoic Rocks of England and Wales. *Quart. Journ. Geol. Soc., vol.* iii., *p.* 136.

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1854.

32. Sedgwick, Rev. Prof. A. — On the May Hill Sandstone and the Palæozoic System of the British Isles. *Quart. Journ. Geol. Soc., vol.* x., *p.* 366 (*abstract*). *Published in Phil. Mag.*

1855.

33. Ruthven, I. - - — An article on the Geology of the District in "A Complete Guide to the English Lakes" by Harriet Martineau.

34. ———— - - — Geological Map of the Lake District.

35. Sedgwick, Rev. Prof. A. — A Synopsis of the British Palæozoic rocks. With a systematic description of the British Palæozoic Fossils in the Geological Museum of the University of Cambridge, by Prof. F. McCoy. *4to. Lond. and Cambridge.*

35*a*. *See* Supplement.

1857.

36. Phillips, Prof. John. — Report on Cleavage and Foliation in rocks, and on the Theoretical Explanation of these Phenomena. *Part* I., *Rep. Brit. Assoc.*, 1856, *p.* 369. (Lake District, pages 1, 4, 9, 80, 378.)

1858.

37. Harkness, Prof. R. — On the Geology of the Caldbeck Fells and the Lower Sedimentary rocks of Cumberland. *Rep. Brit. Assoc. for* 1857, *Trans. Sect., p.* 67.

37*a*. Sedgwick, Rev. Prof. A. — Description of a series of dislocations which have moved the Cambrian and Silurian rocks between Leven Sands and Dudden Sands, several miles out of their normal position in the Geological Map of the Lake Mountains. *Proc. Camb. Phil. Soc., No.* XIII., *pp.* 187–190.

1859.

38. Marshall, J. G. - On the Geology of the Lake District, in reference especially to the Metamorphic and Igneous rocks. *Brit. Assoc. Rep. for* 1858, *Trans. Sect., p.* 84.

39. Phillips, Prof. J. - Notice of some phenomena at the junction of the Granite and Schistose rocks in W. Cumberland. *Rep. Brit. Assoc. for* 1859, *Trans. Sect., p.* 106.

1861.

40. Salter, J. W. - New Fossils from the Skiddaw Slates. *Geologist, vol.* iv., *p.* 74.

1862.

41. Marshall, J. G. - On the relation of the Eskdale Granite at Bootle to the Schistose Rocks, with remarks on the General Metamorphic origin of granite. *Rep. Brit. Assoc. for* 1861, *Trans. Sects., p.* 117.

1863.

42. Harkness, Prof. R. — On the Skiddaw Slate Series, with a note on the Skiddaw Slate Fossils by J. W. Salter. *Quart. Journ. Geol. Soc., vol.* xix., *p.* 113.

1864.

43. ———————— — On the Fossils of the Skiddaw Slates. *Rep. Brit. Assoc. for* 1863, *Trans. Sects., p.* 69.

44. Hull, E. - - — Article on Geology in "The Lake Country" by E. Lynn Linton. *Sm. 4to.*

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1865.

45. HARKNESS, PROF. R. — On the Lower Silurian rocks of the S.E. of Cumberland and the N.E. of Westmoreland. *Quart. Journ. Geol. Soc., vol.* xxi., *p.* 235.

1866.

46. HARKNESS, PROF. R., NICHOLSON, DR. H. A., SALTER, J. W. — Additional observations on the Geology of the Lake Country. With a note on two new species of Trilobites by J. W. Sater. *Quart. Journ. Geol. Soc., vol.* xxii., *p.* 480.

1867.

47. HUGHES, PROF. T. McK. — On the Break between the Upper and Lower Silurian Rocks of the Lake District, as seen between Kirkby Lonsdale and Malham, near Settle. *Geol. Mag., vol.* iv., *p.* 346.

1868.

48. NICHOLSON, DR. H. A. — An essay on the Geology of Cumberland and Westmoreland. 8*vo. London.*

49. ——— — On the Graptolites of the Skiddaw Series. *Quart. Journ. Geol. Soc., vol.* xxiv., *p.* 125.

49*a*. ——— — On the Granite of Shap in Westmoreland. *Trans. Edin. Geol. Soc., vol.* i., *p.* 133.

1869.

50. AVELINE, W. T. - (Letter). On the Relation of the Porphyry Series to the Skiddaw Slates in the Lake Districts. *Geol. Mag., vol.* vi., *p.* 382.

51. DAKYNS, J. R. - Notes on the Geology of the Lake District. *Ibid., p.* 56.

52. ——— - Additional note on the unconformity between the Green and Skiddaw Slate Series. *Ibid., p.* 116.

53. NICHOLSON, DR. H. A. — Notes on certain of the Intrusive Igneous Rocks of the Lake District. *Quart. Journ. Geol. Soc., vol.* xxv., *p.* 435.

54. ——— — On the occurrence of Plants in the Skiddaw Slates. *Geol. Mag., vol.* vi., *p.* 494. With list of Fossils from the Skiddaw Slates.

55. ——— — On the relations between the Skiddaw Slates and the Green Slates and Porphyries of the Lake District. *Ibid., pp.* 105, 167.

56. ——— — Notes on the Geology of Derwentwater. *Trans. Edin. Geol. Soc., vol.* i., *p.* 274.

57. ——— — Notes on the Green Slates and Porphyries of the neighbourhood of Ingleton. *Geol. Mag., vol.* vi., *p.* 213.

1870.

58. HOPKINSON, J. - On the structure and affinities of the genus Dicranograpsus. *Geol. Mag., vol.* vii., *p.* 353.

1871.

59. HARKNESS, PROF. R., NICHOLSON, DR. H. A. — On the Green Slates and Porphyries of the Lake District. *Rep. Brit. Assoc.*, 1870, *Trans. Sects., p.* 74.

60. NICHOLSON, DR. H. A. — Notes on the Lower portion of the Green Slates and Porphyries of the Lake District between Ullswater and Keswick. *Quart. Journ. Geol. Soc., vol.* xxvi., *p.* 599.

61. WARD, J. CLIFTON - On the Development of Land. *Geol. Mag., vol.* viii., *p.* 11.

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1872.

62. Aveline, W. T. - On the Continuity and Breaks between the various Divisions of the Silurian Strata in the Lake District. *Geol. Mag., vol.* ix., *p.* 441.

62*a*. ——— and Hughes, T. McK. Explanation of Quarter-Sheet 98 N.E. *Geol. Survey Mem.*

62*b*. Evans, John - - Ancient Stone Implements. (References to Cumb., pp. 87, 95, 106, 107, 121, 137–139, 173, 178, 179, 200, 201, 215, 228, 236, 295, 316.)

63. Nicholson, Dr. H. A. On the correlation of the Silurian Deposits of the N. of England with those of the S. of Scotland. *Trans. Edin. Geol. Soc., vol.* ii. (*part* i.), *p.* 105.

64. ——— A Monograph of the British Graptolitidæ. *Blackwood & Sons, Edin. and London.*

1873.

64*a*. Hopkinson, J. - On some Graptolites of the Upper Arenig Rocks of Ramsey Island, St. David's. *Geol. Mag., vol.* x., *p.* 519. (Comparison with graptolites of the Skiddaw Slate.)

65. Jenkinson, H. I. - Guide to the Lakes, with Articles on the Geology. *Stanford, London.* (4th edit. in 1874. With list of minerals of the district, by Bryce M. Wright.)

65*a*. *See* Supplement.

66. Ward, J. Clifton - On Rock Fissuring. *Geol. Mag., vol.* x., *p.* 245.

67. ——— - Scenery of the Lake District, geologically considered. *Proc. Brighton and Sussex Nat. Hist. Soc.*, 20th Report, *p.* 39. *Science Gossip*, June 1873.

68. ——— On some Archæological remains in the Keswick District. *Trans. Cumb. and West. Ant. and Archæ. Soc., Part* 2, *p.* 215.

1875.

68*a*. Hopkinson, J., and Lapworth, C. Descriptions of the Graptolites of the Arenig and Llandeilo Rocks of St. David's. *Quart. Journ. Geol. Soc., vol.* xxxi., *p.* 631. (References to the Skiddaw Slate.)

69. Dakyns, J. R., Ward, J. Clifton. (Letter.) Volcanic Rocks of the Lake Country. *Geol. Mag., Dec.* 2, *vol.* ii., *p.* 38.

70. Ward, J. Clifton - Modern Vulcanicity. *Ibid., p.* 38.

71. ——— - Notes on the Microscopic Structure of some Ancient and Modern Volcanic Rocks. *Quart. Journ. Geol. Soc., vol.* xxxi., *p.* 388.

71*a*. ——— - On the Granitic, Granitoid, and associated Metamorphic rocks of the Lake District.
Part I.—On the Liquid-cavities in the quartz-bearing rocks of the Lake District.
Part II.—On the Eskdale and Shap granites, with their associated metamorphic rocks.

71*b*. *See* Supplement . *Ibid., p.* 568.

(*c*.) Works and Papers on the **Mining** of the Keswick District.

1693.

72. Anon. - - - Two letters concerning several Copper Mines, in answer to some Queries proposed by Dr. Lister, F.R.S., who communicated them to the publisher. *Phil. Trans., vol.* xvii. (*No.* 200), *p.* 737. Date of letters is 1684.

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1709.

73. ROBINSON, REV. THOS. An Essay towards a Natural History of Cumberland and Westmoreland, wherein an account is given of their several mineral and surface productions, &c. 8vo.

1720.

74. - - - - Magna Britannia, *vol.* i., *Cumberland Natural Hist., p.* 397.

1740.

75. ANON - - - Account of the Black Lead Mines. *Gentleman's Magazine, p.* 583.

76. SHORT, DR. THOMAS - Essay on the Mineral Waters of Cumb., West., &c., &c. 4to. *Sheffield.*

1774.

76*a*. JARS, — - - Voyages Metallurgiques. 4to. *Lyons.* (Cumberland, 235.)

1794.

77. HUTCHINSON, W. - History of Cumberland. Plumbago Mines. *Vol.* ii., *p.* 212.

1802.

78. BRITTON, J., BRAYLEY, E. W. The Beauties of England and Wales, vol. iii., (Notices of the Minerals of Cumb., pp. 22–30.) 8vo. *Lond.*

1813.

79. SCHRADER, — - Analysis of Graphite. *Ann. of Phil., vol.* i., *p.* 294.

1816.

80. ANON. (a correspondent) Geological Sketch of part of Cumberland and Westmoreland. *Phil. Mag., vol.* xlvii., *p.* 41.

1819.

81. JAMESON, J. - - On the Black Lead of Borrowdale and of Ayrshire. *Edin. Phil. Journ., vol.* i., *p.* 130.

82. OTLEY, J. - - Account of the Black Lead Mine in Borrowdale. *Manchester Mem.*, 2nd *series, vol.* iii., *p.* 168.

1820.

83. DUFRÉNOY, P. A., BEAUMONT, E. DE. Sur le gisement, l'exploitation et le traitement des mineraux d'etain et de cuivre du Cornouailles [continued]. Ann. des Mines, t. x. pp. 331, 401 (Cumberland, p. 407).

84. OTLEY, J. - - Remarks on the Succession of the Rocks in the Districts of the Lakes. *Phil. Mag., vol.* lvi., *p.* 257.

1821.

85. CLARKE, PROF. E. D. - On Crystalline Plumbago and other Minerals from mines of Cumberland. *Ann. of Phil. ser.* 2, *vol.* ii., *p.* 415, *and* (for Cadmium) *vol.* xv., *p.* 273.

1825.

86. VANUXEM, L. - Experiments on Anthracite, Plumbago, &c. *Journ. Acad. Nat. Sci. Philadelphia;* and *Phil. Mag., vol.* lxviii., *p.* 161.

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1826.

87. VANUXEM, L. - - Experiments on Anthracite, Plumbago, &c. *Ann. of Phil., ser.* 2, *vol.* xi., *p.* 104.

1837.

88. TOOKE, A. W. - The Mineral Topography of Great Britain. *Mining Review, No.* 9, p. 39.

1839.

88*a*. DUFRÉNOY, P. A., BEAUMONT, E. DE. COSTE, — PERDORMET, — Voyage Metallurgiques en Angleterre. *t.* II. *Ed.* 2. 8*vo*. Paris (Cumb. pp. 394, 499.)

89. THOMPSON, DR. T. - Notice respecting the Native Diarseniate of Lead (Caldbeck Fells). *Rep. Brit. Assoc.*, 1838. *Trans. Sects., p*, 46.

1848.

90. RANSOME, THOS. - Analysis of a Saline Spring in a Lead Mine, near Keswick. *Man. Lit. and Phil. Soc., ser.* 2, *vol.* viii., *p.* 399.

91. SEDGWICK, REV. PROF. A. Suggestions on the Origin of Plumbago. *Quart. Journ. Geol. Soc., vol.* iv., *p.* 216.

1865.

92. ANON. (D. M.) - Mining Notes. *Geol. Mag., vol.* ii., *p.* 94.

1871.

93. SMITH, J. T. - - Iron Ores Committee, Cumb. and Lancas. *Iron and Steel Institute, vol.* ii., p. 2.

1875.

93*a*. GOODCHILD, J. G. - Wulfenite at Caldbeck Fell. *Geol. Mag., Dec.* 2, *vol.* ii., *p.* 565.

93*b*. *See* Supplement.

(*d*.) WORKS AND PAPERS ON THE **Glacial Geology** OF THE LAKE DISTRICT.

1825.

94. SEDGWICK, REV. PROF. A. On the origin of Alluvial and Diluvial Formations. *Ann. of Phil., ser.* 2, *vol.* ix., *p.* 241, and *vol.* x., *p.* 18 (Cumberland, pp. 26–32).

1837.

95. PHILLIPS, PROF. JOHN On the removal of large blocks or boulders from the Cumbrian Mountains in various directions. *Brit. Assoc. Rep.*, 1836, *p.* 87.

1840.

96. BUCKLAND, REV. DR. W. On the evidences of Glaciers in Scotland and the N. of England. *Proc. Geol. Soc., vol.* iii., *pp.* 332, 345.

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1841.

97. AGASSIZ, PROF. L. - On Glaciers and the evidence of their having once existed in Scotland, Ireland, and England. *Proc. Geol. Soc., vol.* iii., *p.* 327.

1845.

98. DAVY, DR. J. - - Observations, chiefly meteorological, made at Ambleside. (Former existence of Glaciers in Cumberland, *p.* 10.) *Edin. New Phil. Journ., vol.* xxxix., *p.* 1.

1850.

99. BRYCE, DR. J. - - On Scratched and Polished Rocks, and Roches Moutounées in the Lake District of Westmoreland. *Rep. Brit. Assoc.* 1850, *Trans. Sects., pp.* 76, 112; *Phil. Mag., ser.* 3, *vol.* xxxvii., *p.* 486. (*postscript in* 1851).

1853.

100. CHAMBERS, R. - - On Glacial Phenomena in Scotland and parts of England. *Edin. New Phil. Journ., vol.* liv., *p.* 229.

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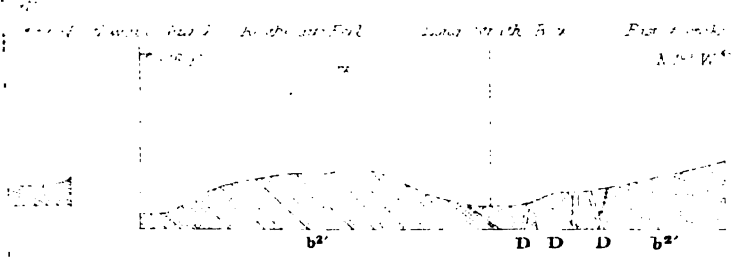

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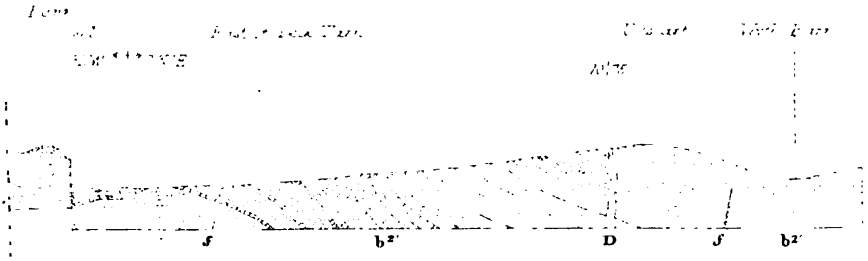

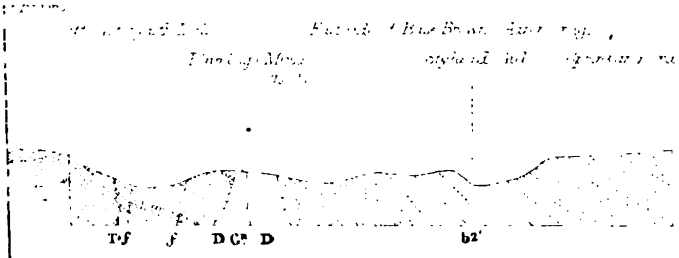

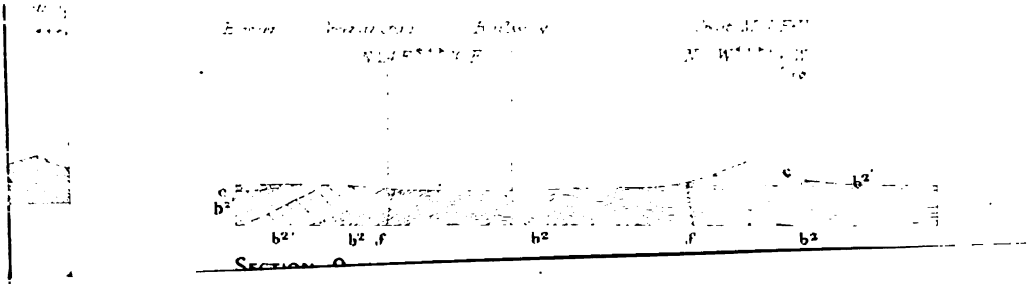

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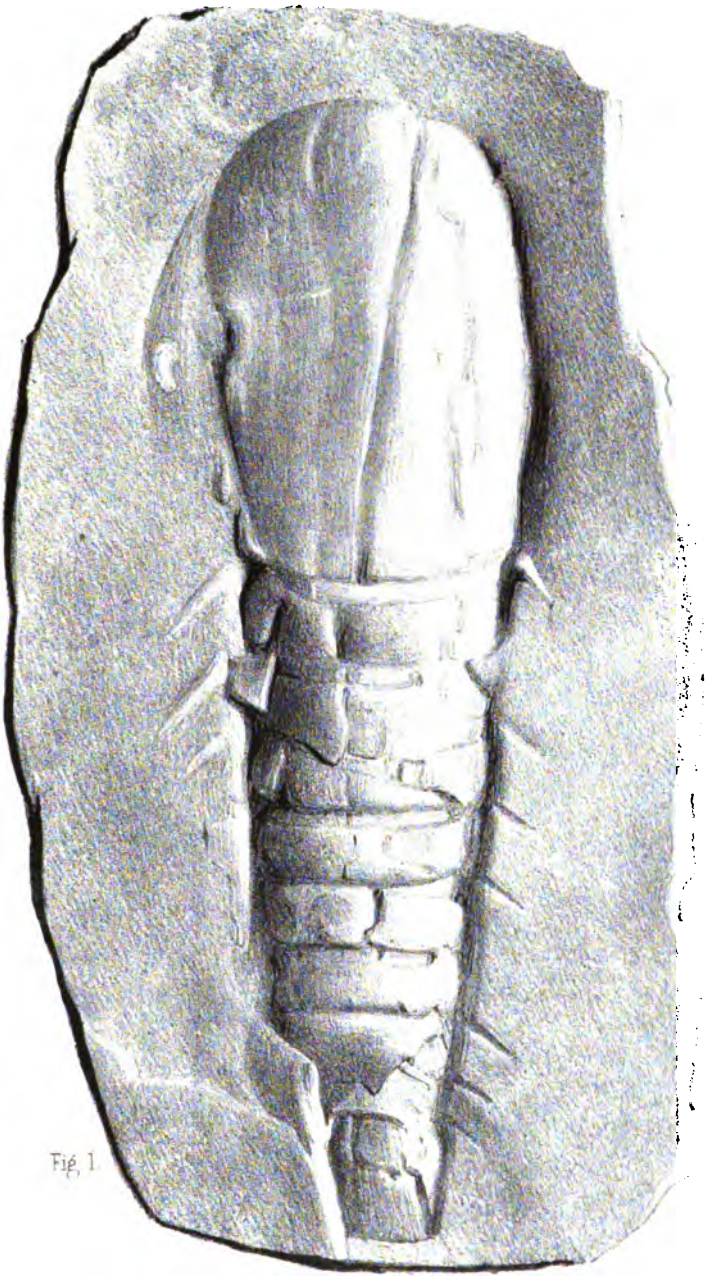

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Fig. 2.

Æglina Sp.
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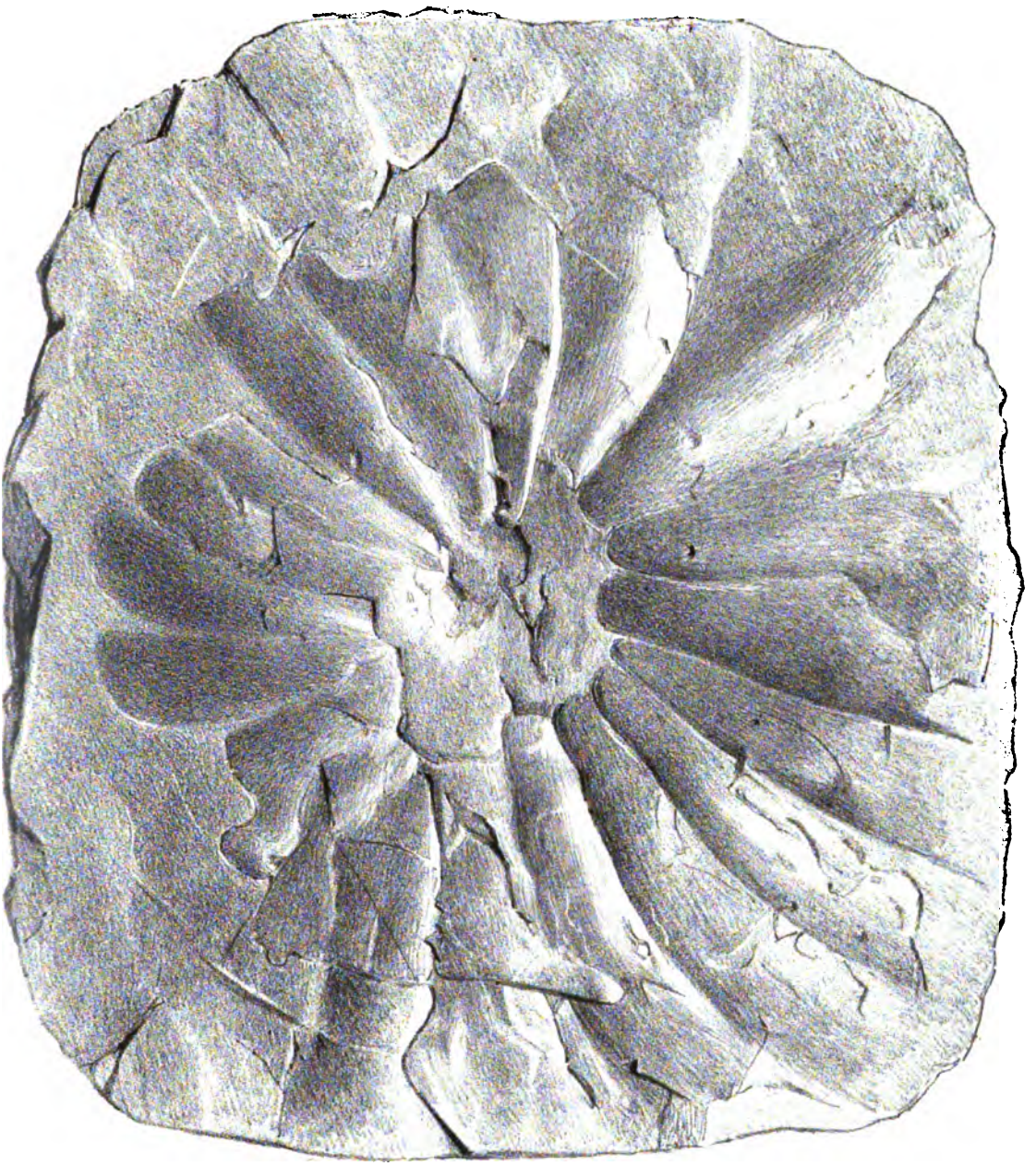

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